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W W Hugette
Toronto June 24. 1905

M. C. HUYETT,

Heating and Ventilating Engineer,

CONSULTING ENGINEER,

EXPERT WITNESS IN LEGAL CASES,

— AND —

Superintendent of Large Constructions.

Plans and Specifications for Heating and Ventilating Apparatus analyzed and Expert Reports made without fear or favor for Architects and Owners.

Plans and specifications for Heating and Ventilating, Power and Electrical Installations made for Architects and Owners.

MONADNOCK BUILDING,

CHICAGO, ILL.

TO ARCHITECTS.

The following pages present the essentials of heating and ventilation; the tables are original and are given to aid in the development of your part of plans on a scientific basis. It is information which has been withheld by manufacturers and engineers.

To provide satisfactory and economical heating and ventilating apparatus is a problem in proportion; when correctly solved, success is certain.

M. C. HUYETT,

Heating and Ventilating Engineer.

Monadnock Building, Chicago, Illinois.

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MECHANICAL

HEATING AND VENTILATION

AN EXHAUSTIVE ANALYSIS
OF ALL SYSTEMS.

SECOND EDITION.

BY
M. C. HUYETT.
MONADNOCK BUILDING, CHICAGO, ILL.

PRICE $5.00.

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INTRODUCTORY.

Heating and ventilation have been treated from a theoretical standpoint on the basis of generalities by most writers; that which has been put in book form, in the main, relates to heating, and is of little or no value with regard to ventilation.

With regard to the science of heating and ventilation, the mechanical developments of which are in as universal use as any appliances in the world, more ignorance prevails than in any other branch.

Heating and ventilation as applied has been a series of experiments which in most cases have been failures.

In analyzing mechanisms and methods, the matter has been treated from the standpoint of that of a critical engineer, and free from purpose to favor friends or punish enemies; the keen analysis, fearless criticisms and specific statements of facts have been made necessary by reason of conditions peculiar to the business of heating and ventilation as conducted

Nothing of value to architects, engineers and the general public has knowingly been withheld. I have given tables, rules, reliable data and examples, comprehensively, for the purpose of making a true basis for general engineering practice.

If I can increase knowledge — so that competitions shall base on truth and facts — make better conditions in homes, schools, churches and public buildings, human life will be lengthened, thereby enriching the world and adding to the sum of human happiness.

M. C. Huyett, H. V. Eng.

CHICAGO, Ill., 1895.

Mechanical Heating and Ventilation.

HEATING and ventilation, as a branch in sanitary science, has within a few years been receiving much attention, with the result that more progress has been made in providing healthful conditions than in any twenty-five preceding years; it is a special branch in engineering in which a man can become an expert only when practical experience with the details of the construction and application of parts and mechanism shall form the basis of analysis, by which fact shall be separated from theory, and the laws which govern heat and cold and the movement of air currents shall be learned.

The subject has been treated from a theoretical standpoint by most writers; in no "text-book," so-called, can anything be found helpful, or even suggestive, which will aid architects in proportioning flue areas required for heating and ventilation.

In all the activities of life the specialist becomes most expert; the grand movement of material development made within the last ten years has, in the main, been made by specialists — "men of one idea" — who concentrated time, thought and money to accomplish a definite purpose.

Unreasonably, the impossible is expected of architects; necessarily, they must have creative minds; it is expected of them that they shall know as much of carpentery as the carpenter, of masonry as the mason, of plumbing as the plumber, and of heating and ventilating as the heating and ventilating engineer; it is impossible that they shall have practical experience in each and every branch of work entering into construction. Such being the fact it is my purpose to direct attention to essential elements and incorporate tables which will aid architects. Data, for estimating the parts, speed, and fan capacities, pressures, etc., for mechanical heating and ventilating plants, has not been put in print, the engineering is confined to a few persons, half or more of whom are theorists — men without practical experience — who accept manufacturers' printed tables as truth.

Good heating and ventilating apparatus consists of apparatus which will warm the air in an inclosed space to a temperature

conducive to comfort and health, and supply a volume of air sufficient to maintain a sanitary standard of purity; both conditions — heating and ventilation — must be controllable, constant, safe and economical, with the air deliveries so made that occupants shall not be exposed to cold drafts. In plan and application of apparatus the two requirements must be treated as a unit—they are inseparable, and together form a complete whole.

Efficiency, sufficiency, safety, durability and economy, with the installation so simple that any person of average intelligence shall be competent to operate, are the prime factors to be considered in providing parts and mechanisms for a modern sanitary heating and ventilating plant.

VENTILATION.

Ventilation is the renewal of air by supply at one or more places into and displacement of foul air from an inclosed space; it is a gradual, constant and complete changing of the air in a structure, a substitution of fresh air for foul air.

Sanitists agree that air which contains seven parts carbonic dioxide in 10,000 parts, as the result of respiration, is no longer fit for use, and ten parts in 10,000 is slow poison; normal air contains 3 to 4 parts in 10,000. Chemical analysis establishes the fact that air in schoolrooms ranges from 14 5 to 32 parts carbonic dioxide in 10,000 parts; in fact, is worse than that of a well-kept sewer. Professor Kedzie gives 24.0 parts carbonic dioxide in 10,000 parts as the average in eleven high and normal schools in the state of Michigan.

For ventilation the volume of fresh air to be supplied should be based on the number of occupants, terms of occupancy, and to some extent on kind of occupancy, and be delivered regardless of varying internal and external temperatures, and velocity and direction of external air currents. "Breathing space" is not a factor in estimating the air supply required.

NATURAL LAWS.

In heating and ventilation, the conditions predominating, and the natural laws which make the conditions and govern, must be regarded, otherwise all applications will be experimental.

First. Air in a building or room is in motion, its direction and velocity caused and controlled by location and area of glass exposures, exterior temperature, location of heat supply, location of

ventilating outlets, direction and velocity of external air currents, kind of occupancy, and, to some extent, the number of occupants; separate from the different factors specified, the motions of air, by the force of gravity, are precisely like those of fluids.

A movement of air

88 feet	per minute	is	1 mile	per hour,		barely observable.
176 "	"	"	2 miles	"	}	just perceptible.
264 "	"	"	3 "	"	}	just perceptible.
352 "	"	"	4 "	"		light breeze.
440 "	"	"	5 "	"		gentle wind.

Second. Air, in a room, in motion IS EFFECT; if it produces discomfort, the cause should be located and a proper remedy be applied.

Third. Air occupies space the same as solids and liquids, but because it is invisible, it is not so regarded.

Fourth. Cold air falls because of its density, and heated air rises because of its rarity.

Fifth. Carbonic acid gas, transmitted through the pores of the skin and expelled from the lungs by respiration, the result of internal combustion, is half again as heavy as pure air and falls by reason of its weight.

Sixth. A given volume of air occupies a given space; a like volume cannot occupy the same space at the same time.

Seventh. A volume of air can be delivered into a room only equal to the quantity displaced therefrom; when a space is full it can hold no more.

Eighth. A volume of air only equal to the quantity that leaks in, or is admitted through openings made therefor, can be exhausted from a room.

Ninth. Natural means for purifying air is the action of winds diffusion, oxidation and the fall of rain, neither of which affects rooms which by reason of their construction are practically hermetically sealed boxes.

Tenth. A building or room so constructed as to make necessary the opening of doors, or windows, to admit fresh air, is not properly ventilated; open a door or window and a two-fold current is immediately produced; cold air, by reason of its weight, falling into the room, and displacing a like quantity of warmer air which passes outward, mainly through the same opening, the flow decreasing in proportion as an equilibrium of temperature is established as between the inner and outer air.

Eleventh. Persons sitting between a window and the source of

heat supply are in a cold draft and usually "take cold"; they honestly believe that the draft is caused by ill-fitting sashes; make the sashes air-tight fit and the result will be the same.

In extreme winter weather the downflow of cold air produced by glass surfaces will cause light curtains to vibrate, in velocity is equivalent to from four to five miles an hour.

Tests can be made by blowing smoke in an upward direction against glass surfaces; if it be expelled from the mouth its temperature will be about 98°, and according to all preconceived notions should rise, but following a natural law it will almost instantly fall to the floor line and travel toward the source of heat supply.

Twelfth. Apparatus which will warm a building to a proper temperature in the shortest time with the least expense for fuel, will maintain the after required temperature at the lowest cost.

Thirteenth. It is impossible to exhaust air from a room in excess of the quantity admitted, and it is impracticable to admit air to a room unless it has previously been warmed.

Fourteenth. The transmitting power of various building surfaces and their cold-draft producing powers, relatively, are:

Oak and walnut	65
Window glass	1,000
White pine	80
Pitch pine	100
Lath and plaster	75 to 100
Brick	200 to 250
Iron	1,030 to 1,110

Fifteenth. A stove ventilates to the extent of the volume of air admitted to the combustion chamber; when the draft is closed ventilation ceases.

Sixteenth. An open fireplace *with a fire in it* ventilates to the extent of the quantity of air that can leak in about window sashes and doors; to that extent it is an air ejector exhausting air from a room which by the natural law of gravity and atmospheric equilibrium is replaced by cold air. When an open fireplace has no fire in it, in cold weather, cold air will fall into a room in volume equal to the leakage of warmer air outward caused by heavier—cold air—falling into and occupying a lower space than the warm air; this action will decrease in proportion as an equilibrium, as regards internal and external temperature, shall be restored. Make a room air-tight except a keyhole in the door, and

the volume of ventilation can be measured by the quantity of air that can leak in through that hole.

Seventeenth. High and low pressure steam and hot-water systems with radiators in rooms will provide HEAT, but *ventilation is impossible;* it is true in most cases flues FOR ventilation are provided, but they *do not ventilate.*

Eighteenth. Direct-indirect heating has been applied to a limited extent; has never been a success, in most instances the indirect has been abandoned; practically the system is obsolete.

Nineteenth. Indirect heating provides ventilation in proportion to the area of radiating surface and its exposure to air contact, temperature of radiating surface, temperature of exterior air, direction and velocity of external air currents, atmospheric pressure, size and height of ventilating flues and quantity of heat force applied therein; as a result the volume of ventilation is inconstant and uncontrollable.

Tables and data in text-books—so-called—on heating and ventilating are based on *experiments*, not practical working plants, and are of no value whatever in proportioning a mechanical system. "Sanitary experts" attached to health commissions, and some architects, manifest their ignorance of fundamental principles by advocating that ventilating flues "should have the exit openings near the ceiling, for the reason that the temperature of the air in the room being at 70° Fahr., and air expelled from the lungs being about 98°, the foul product of respiration will first rise and later descend to the breathing line in its travel toward floor line exits." In part that is true when "natural means" for ventilation is used, and is the result of lack of volume of air supply to give diffusion, and lack of pressure of air delivered above breathing lines with travel downward and toward exit openings.

The facts are, carbonic dioxide in weight is 1.5, as compared with 1 for pure air, and falls because of its weight; applying their theory the lighter gases would pass upward and outward with the warmest and most pure air, while carbonic dioxide and cooled vapor of water — the most poisonous results of respiration and transpiration — following the natural law of gravity will remain in the room, and to which can be added the cold transmitted by glass exposures and leakage inward about window sashes; with that condition sufficient heating, good ventilation, and an equable temperature *is impossible.*

Under "natural conditions" the heat force—is always applied at or near floor lines, causing *ascending air currents;* with

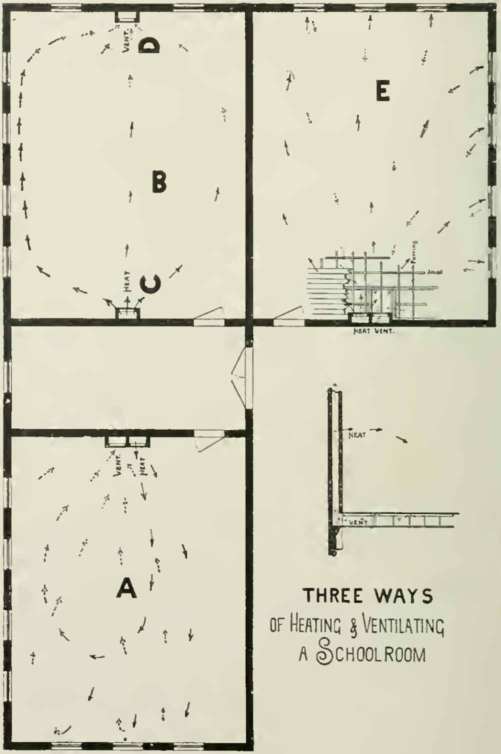

VENT.
D
B
HEAT
C
E
HEAT VENT.
VENT.
HEAT
A
HEAT
VENT
THREE WAYS
OF HEATING & VENTILATING
A SCHOOLROOM

FIG. 1.

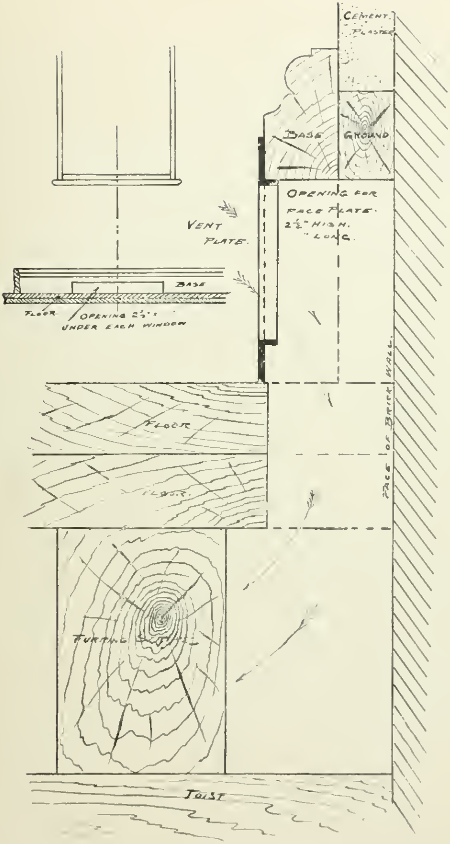


FIG. 2.
Detail of displacement openings and ventilating space under floors; double floor is not arbitrary.

mechanical heating and ventilation, properly applied, the heat inlets are placed above head lines and the exit to ventilating risers at floor lines, so that the large, constant, controllable volume of pure air presses the foul product downward and outward with as much certainty as water will drain out of a pail if a hole shall be made in its bottom. VOLUME GIVES DIFFUSION, PRESSURE DISPLACEMENT, and GRAVITY settles the question as to which stratum of air shall first and continuously be displaced.

"A" shows ventilating flues as ordinarily applied; with direct heating it does not matter WHERE the ventilating flues shall be placed, *they do not ventilate*—"no more air can be exhausted than the quantity admitted," and no provision is made for air inflow.

"B" shows a correct placing of flues for indirect heating—natural or mechanical—if floor surface exit opening shall be used; the travel of the warmed air will be from "C" toward "D," and will give diffusion. The main objection to that plan is the fact that cold transmitted by glass exposures and which leaks inward about sashes falls to floor lines and travels toward the exit openings, exposing the feet and legs of occupants to cold drafts unless the air at and above the breathing line shall be overheated. "A" is the worst possible plan for displacement with any indirect system.

"E" shows the most sensible, efficient, and economical system for displacement possible. When applied, the ventilating riser can be placed at will, the only essential being that where joists do not end in the wall in which the riser is placed, a "trimmer" must be set back six or eight feet with two joists extending therefrom to the wall in which the riser is placed, for reservoir, in order that its sides shall give free inlet for air to gather for entering the opening placed between the ceiling and joist line. When this application is made, cold transmitted by glass surfaces, and cold air which leaks inward about sashes, *is displaced where transmitted* and passes outward under floor lines without contact with the occupants. If heat shall enter at the south end of a room and the wind be from the north, the warm current will travel toward the points of displacement and be diffused; it means at least ten per cent lessened fuel bills, increased comfort, and healthful conditions.

HOW MUCH VENTILATION?

"Pure air, pure water, wholesome food, comfortable clothing, cleanliness of person and cleanliness of surroundings are essential

hygienic conditions without which there can be no promise of individual or public health ;"* except the first element they are conditions which pertain to home life to a greater degree than at any time in the past, and would strengthen and add to the longevity of human life, but for the fact that in schoolrooms, churches and public halls the seeds of disease and future enfeebled constitutions are being sown by means of overheating, cold drafts, and impure air the result of insufficient ventilation.

What quantity of pure air shall be supplied, and how shall the requirements be measured, must now be determined. We determine the quantity of food required by the quantity consumed, approximately a measurable quantity ; with greater accuracy we may determine the required volume of air supply, using as a basis the quantity of air breathed and thus vitiated and the volume additional which this breathed air will contaminate.

"The average individual exhales at each respiration nearly one cubic inch of carbonic dioxide with which is associated other poisonous matter ; the addition of this one cubic inch to the carbonic gas already contained in the air increases the quantity to three cubic inches — the maximum degree of impurity which can be tolerated by the system without danger, and thus renders that quantity of air unfit for further respiration.

"It thus appears that with each breath each individual contaminates 5,000 cubic inches, approximately three cubic feet. As a person breathes about twenty times a minute the amount of air required by each individual per minute is three times 20, or 60 cubic feet ; multiplying this result by 60 gives 3,600 as the number of cubic feet of pure air required by each person to replace air which has been contaminated by the process of respiration in one hour.

"If this quantity is not obtained, the proportion of organic impurities increases until the air becomes so intensely poisonous as to be productive of serious disease."† In schoolrooms the breathing space is, as a rule, limited to less than 200 cubic feet per pupil ; for 200 cubic feet, Dr. Parkes gives 2,800 cubic feet as the quantity required for the first hour and 3,000 cubic feet per pupil per hour thereafter.

Charles H. Haswell is accepted as standard authority worldwide ; in his handbook, page 84, he states : "An average-sized man will exhale from his lungs and body from .6 to .7 of a cubic

*John Avery, M.D., President Michigan State Board of Health.

†J. H. Kellogg, M.D., of Michigan State Board of Health.

foot of carbonic acid per hour. Assuming, then, that there are four volumes of carbonic acid in 10,000 parts of air, and that a man in a room with a lighted lamp or candle furnishes from 1.2 to 1.4 cubic feet of acid per hour, there will be required to maintain the air at the required conditions for one person, the allowable pollution of it being six volumes in 10,000, fully 3,000 cubic feet of fresh air per hour." By experiments made in Paris it was shown that there were required from 2,400 to 3,120 cubic feet of air per hour.

No person will use food or water which has been in the mouth of another person, yet the neglect to supply the known quantity of pure air for ventilation forces people to breathe air which has been time and time again in contact with the mouth or nostrils and throat and lungs of hundreds of persons more or less diseased; it is not pleasant contemplation, but the condition is an existing fact.

In a mechanical system, circulation or displacement — ventilation — is a prime essential in order to secure heat diffusion; quantity is a factor to be considered.

For Factories in which apparatus shall be operated on the basis of circulation, i. e., warming the same air over time and again without displacement, the air circulation should be equal to circulating the cubical contents $2\frac{1}{2}$ times per hour.

For School Buildings.—1,800 cubic feet of air per pupil per hour; corridors, cloak and play rooms, change of air three times per hour, and for toilet rooms change of air six times per hour.

For Churches and Sunday-School Rooms.—Change of air four times per hour for the entire structure; ordinarily the full volume can be cumulated on the auditorium — with a small supply to one or two small rooms and the vestibule, and at other times the full volume can be delivered to the chapel parts; this will increase the ventilation on the different parts of the structure, when used, equal to changing the air six to eight times per hour at the times of greatest need.

For Courthouses and other public buildings in which long continued sessions are held the change of air should base on five times per hour, with a possible six times change.

For Hospitals.—Change of air six times per hour at ordinary working speed of fan wheel, with a possible seven times change.

For Toilet Rooms.—Change of air six times per hour.

INITIAL VELOCITIES OF AIR TO ROOMS.—The inflow velocities of air to rooms depends on the size and the nature of the occu-

pancy; for factories 15 feet to 20 feet, and for schoolrooms and churches 10 feet to 15 feet, and under some conditions 20 feet velocity per second is admissible. Heat riser and ventilating flue areas should base on initial velocities desired.

Vestibules and corridors should have initial velocities 20 feet per second, with the volume of air delivered into pedestal screens in order that the heat product shall be diffused at low levels. Persons entering when wet or cold can warm or dry themselves quickly without monopolizing. Under ordinary conditions, when a door opening to exterior shall be opened there is an in-rush of cold air at and near floor lines pushing outward a like quantity of warm air from the higher level. If applications be made as specified for vestibules, the inflow of cold air will be greatly reduced and comfortable temperature be maintained. Vestibule space will warm sufficiently in less than half an hour from the time heat shall be turned on.

INSUFFICIENT VENTILATION.

"TWENTY-FIVE SOUTH DAKOTA MEMBERS SERIOUSLY ILL, AND TWO HAVE DIED.

"SIOUX FALLS, S. D., March 7.—Twenty-five members of the legislature are seriously ill here. Two have died during the session, and one today is reported on his deathbed. The general ailment is pneumonia. Inadequate ventilation in the statehouse, which permits of a multitude of drafts, has caused the whole trouble. The legislature adjourned this morning, having failed by one vote to carry the bill for resubmission of the prohibition amendment." . . . .

But cause is not removed, and effect continues to add to death's victims.

"DURBOROW AND OTHERS OF VENTILATION COMMITTEE CALL ON CAPITOL ARCHITECT.

Special to the Chicago *Daily News*.

"WASHINGTON, D. C., June 21.—Representative Durborow and his colleagues on the committee on ventilation and acoustics have made up their minds to oust Col. Edward Clark, architect of the capitol.

"Yesterday Mr. Durborow, accompanied by several members of the committee, called on the architect and requested his resignation, but he declined to comply with their wishes and the committee has decided to report a resolution requesting him to resign.

"The reason for requesting the architect to resign is the bad sanitary condition of the capitol. Recently the committee of which Mr. Durborow is a member made a careful personal inspection of the capitol building and found that the basements were stored with musty old documents in a state of neglect, and that the air ducts and ventilating pipes were choked with filth, causing deleterious ventilation and an unwholesome and poisonous atmosphere to flow into the house of representatives. These facts were set forth in a report made to the house and occasioned considerable surprise.

"Architect Clark has served in his present capacity since 1865, succeeding Thomas W. Walter, the architect who superintended the construction of the two wings of the capitol. Mr. Clark himself had been Walter's assistant and as such had charge of a number of important pieces of government work."

"WASHINGTON, D. C., June 8, 1894.—The day's proceedings in the house were enlivened by Mr. Walker's (Rep., Mass.) complaint of the poor ventilation of the house and the incapacity of the architect of the capitol."

That is a specimen of telegraph dispatches yearly from Washington. It would be just as reasonable to employ a heating and ventilating expert to make detail drawings and specifications for an elaborate capitol building as to have an architect make the plans, estimates and specifications for an elaborate modern sanitary heating and ventilating plant.

From the capitol at Washington down to the latest completed large public building, with but few exceptions, the history is alike, "*unsatisfactory*"—*cause* remains and *effect* continues; notwithstanding these facts, in the next public building, or school, *like causes will be incorporated and like effects produced.*

CALL IN THE DOCTOR.

When a person is sick the doctor is called; when a surgical operation is necessary the surgeon is called; when electrical appliances are needed the electrical expert is called in for consultation; when an elaborate steam plant is to be installed a mechanical engineer is retained; but when heating and ventilating apparatus is required any "jack-at-all-trades"—steamfitter—is considered competent (?), or at best the plans and specifications are made by persons who have had *no practical experience with the details of construction and application;* flues for ventilation are planned and built, but they *do not ventilate;* the general public

— the sufferers — condemn the building, while *the guilty maker of the conditions escapes the just indignation.*

PROPORTIONING AREAS OF HEAT RISERS AND VENTILATING FLUES.

Conditions are seldom alike; consequently no ironclad rule can be stated for initial velocities. The judgment of a heating and ventilating engineer, based on practical experience, is the only safe guide. Velocities must base on size and exposures of rooms, kind of occupancy, and location and distribution of displacement openings.

The arbitrary tables, in text-books, for "loss of heat units" per square foot of glass and wall exposures, based on air temperatures of 32° Fahr. and "natural means" for diffusion without ventilation, are absolutely worthless as factors in determining proportions for the parts of a mechanical heating and ventilating plant; their use is simply a scholarly method of guessing.

RULE FOR COMPUTING PIPE AND RISER AREAS FOR HEATING AND VENTILATION, BASED ON CHANGING AIR TIMES PER HOUR.

V= Velocity in feet per second.
T=Times per hour.

V	10′	15′	20′	25′	30′	35′	40′	45′
T.								
2	.8	.53	.4	.32	.26	.23	.2	.18
3	1.2	.8	.6	.48	.4	.34	.3	.26
4	1.6	1.06	.8	.64	.53	.46	.4	.35
5	2.	1.33	1.	.8	.66	.57	.5	.44
6	2.4	1.6	1.2	.96	.8	.68	.6	.53
7	2.8	1.86	1.4	1.12	.93	.8	.7	.62
8	3.2	2.13	1.6	1.28	1.06	.91	.8	.71
9	3.6	2.4	1.8	1.44	1.2	1.03	.9	.8
10	4.	2.66	2.	1.33	1.33	1.14	.10	.89

RULE.—To ascertain square inches of flue area necessary to change the air in a room a required number of times per hour with a fixed initial air inflow, multiply height, width and length together — equals cubic feet of air space; strike off two figures from the right and multiply the remaining figures by figures, at chosen

velocity, in column opposite the number of times per hour the air contents is to be changed.

Example.—A room 23 by 32 by 14 feet high, the air of which shall be changed four times per hour, with an initial velocity of 10 feet per second; $23 \times 32 \times 14 = 10.304$

$$\begin{array}{r} 1.6 \\ 61.8 \\ \underline{103.} \\ 164.8 \end{array}$$

square inches flue area, to which should be added five to ten per cent for friction — dependent on length.

That gives area (in square inches) of heat riser, also ventilating flue for mechanical heating and ventilation.

To change the air in the room four times per hour requires 41.216 cubic feet per hour; at 10 feet velocity per second a flue with 164.8 square inches area has capacity for delivering 41.205 cubic feet per hour — not allowing for friction.

Velocity of air travel, and pressure, are factors in engineering which can be determined only when volumes of air required, exposures, and building details are known.

RULE TO DETERMINE AREA OF HEAT AND VENTILATING RISERS WHEN VENTILATION BASES ON A REQUIRED QUANTITY PER PERSON PER HOUR.

Multiply the number of persons to occupy by the quantity of air per hour to be supplied per person, the result will equal the quantity per hour required; find that quantity in the table, and in the column opposite the required flue area will be found.

At 10 feet initial velocity per second.

Factor, 432,000; no allowance made for friction.

7,000	cubic	feet	per	hour	= 28	square	inches	area.
9,500	"	"	"	"	38	"	"	"
12,500	"	"	"	"	50	"	"	"
19,439	"	"	"	"	78	"	"	"
23,576	"	"	"	"	95	"	"	"
25,000	"	"	"	"	100	"	"	"
26,250	"	"	"	"	105	"	"	"
27,500	"	"	"	"	110	"	"	"
30,000	"	"	"	"	120	"	"	"
32,500	"	"	"	"	130	"	"	"
35,000	"	"	"	"	140	"	"	"

37,500	cubic	feet	per	hour =	150	square inches	area.
40,000	"	"	"	"	160	"	" "
42,500	"	"	"	"	170	"	" "
45,000	"	"	"	"	180	"	" "
47,500	"	"	"	"	190	"	" "
50,000	"	"	"	"	200	"	" "
52,500	"	"	"	"	210	"	" "
55,000	"	"	"	"	220	"	" "
57,500	"	"	"	"	230	"	" "
60,000	"	"	"	"	240	"	" "
62,500	"	"	"	"	250	"	" "
65,000	"	"	"	"	260	"	" "
67,500	"	"	"	"	270	"	" "
70,000	"	"	"	"	280	"	" "
72,500	"	"	"	"	290	"	" "
75,000	"	"	"	"	300	"	" "
77,500	"	"	"	"	310	"	" "
80,000	"	"	"	"	320	"	" "
82,500	"	"	"	"	330	"	" "
85,000	"	"	"	"	340	"	" "
87,500	"	"	"	"	350	"	" "
92,500	"	"	"	"	370	"	" "
97,500	"	"	"	"	390	"	"
100,000	"	"	"	"	400	"	" "
105,000	"	"	"	"	420	"	" "
110,000	"	"	"	"	440	"	" "
115,000	"	"	"	"	460	"	" "
120,000	"	"	"	"	480	"	" "
125,000	"	"	"	"	500	"	" "
130,000	"	"	"	"	520	"	" "
135,000	"	"	"		540	"	" "
140,000	"	"	"		560	"	" "
145,000	"	"	"	"	580	"	" "
150,000	"	"	"	"	600	"	" "
155,000	"	"	"	"	620	"	" "
160,000	"	"	"		640	"	" "
165,000	"	"	"		660	"	" "
170,000	"	"	"	"	680	"	" "
175,000	"	"		"	700	"	
180,000	"	"	"	"	720	"	" "
185,000	"	"	"	"	740	"	" "
190,000	"	"		"	760	"	" "

200,000	cubic	feet	per	hour	= 800	square	inches	area.
210,000	"	"	"	"	840	"	"	"
220,000	"	"	"	"	880	"	"	"
230,000	"	"	"	"	920	"	"	"
240,000	"	"	"	"	960	"	"	"
250,000	"	"	"	"	1,000	"	"	"
260,000	"	"	"	"	1,040	"	"	"
270,000	"	"	"	"	1,080	"	"	"
280,000	"	"	"	"	1,120	"	"	"
290,000	"	"	"	"	1,160	"	"	"
300,000	"	"	"	"	1,200	"	"	"

At 15 feet initial velocity per second.

Factor, 648,000; no allowance made for friction.

7,500	cubic	feet	per	hour	= 20	square	inches	area.
11,250	"	"	"	"	30	"	"	"
15,000	"	"	"	"	40	"	"	"
18,750	"	"	"	"	50	"	"	"
22,500	"	"	"	"	60	"	"	"
26,250	"	"	"	"	70	"	"	"
30,000	"	"	"	"	80	"	"	"
33,750	"	"	"	"	90	"	"	"
37,500	"	"	"	"	100	"	"	"
41,250	"	"	"	"	110	"	"	"
45,000	"	"	"	"	120	"	"	"
48,750	"	"	"	"	130	"	"	"
52,500	"	"	"	"	140	"	"	"
56,250	"	"	"	"	150	"	"	"
60,000	"	"	"	"	160	"	"	"
67,500	"	"	"	"	180	"	"	"
75 000	"	"	"	"	200	"	"	"
82,500	"	"	"	"	220	"	"	"
90,000	"	"	"	"	240	"	"	"
97,500	"	"	"	"	260	"	"	"
105,000	"	"	"	"	280	"	"	"
112,500	"	"	"	"	300	"	"	"
120,000	"	"	"	"	320	"	"	"
127,500	"	"	"	"	340	"	"	"
135,000	"	"	"	"	360	"	"	"
142,500	"	"	"	"	380	"	"	"
150,000	"	"	"	"	400	"	"	"
157,500	"	"	"	"	420	"	"	"

165,000 cubic feet per hour = 440 square inches area.
172,500 " " " " 460 " " "
180,000 " " " " 480 " " "
187,500 " " " " 500 " " "
195,000 " " " " 520 " " "
202,500 " " " " 540 " " "
210,000 " " " " 560 " " "
217,500 " " " " 580 " " "
225,000 " " " " 600 " " "
232,500 " " " " 620 " " "
240,000 " " " " 640 " " "
247,500 " " " " 660 " " "
255,000 " " " " 680 " " "
262,500 " " " " 700 " " "
270,000 " " " " 720 " " "
277,500 " " " " 740 " " "
285,000 " " " " 760 " " "
292,500 " " " " 780 " " "
300,000 " " " " 800 " " "
307,500 " " " " 820 " " "
315,000 " " " " 840 " " "
322,500 " " " " 860 " " "
330,000 " " " " 880 " " "
337,500 " " " " 900 " " "
345,000 " " " " 920 " " "
352,000 " " " " 940 " " "
360,000 " " " " 960 " " "

At 20 feet initial velocity per second.

Factor, 854,000; no allowance made for friction.

5,000 cubic feet per hour = 10 square inches area.
7,500 " " " " 15 " " "
10,000 " " " " 20 " " "
12,500 " " " " 25 " " "
15,000 " " " " 30 " " "
17,500 " " " " 35 " " "
20,000 " " " " 40 " " "
22,500 " " " " 45 " " "
25,000 " " " " 50 " " "
27,500 " " " " 55 " " "
30,000 " " " " 60 " " "
32,500 " " " " 65 " " "

35,000	cubic	feet	per	hour =	70	square	inches	area.
40,000	"	"	"	"	80	"	"	"
45,000	"	"	"	"	90	"	"	"
50,000	"	"	"	"	100	"	"	"
55,000	"	"	"	"	110	"	"	"
60,000	"	"	"	"	120	"	"	"
65,000	"	"	"	"	130	"	"	"
70,000	"	"	"	"	140	"	"	
75,000	"	"	"	"	150	"	"	"
80,000	"	"	"	"	160	"	"	"
85,000	"	"	"	"	170	"	"	"
90,000	"	"	"	"	180	"	"	"
95,000	"	"	"	"	190	"	"	"
100,000	"	"	"	"	200	"	"	"
105,000	"	"	"	"	210	"	"	"
110,000	"	"	"	"	220	"	"	"
115,000	"	"	"	"	230	"	"	"
120,000	"	"	"	"	240	"	"	"
125,000	"	"	"	"	250	"	"	"
130,000	"	"	"	"	260	"	"	"
135,00	"	"	"	"	270	"	"	"
140,000	"	"	"	"	280	"	"	"
145,000	"	"	"	"	290	"	"	"
150,000	"	"	"	"	300	"	"	"
155,000	"	"	"	"	310	"	"	"
160,000	"	"	"	"	320	"	"	"
165,000	"	"	"	"	330	"	"	"
170,000	"	"	"	"	340	"	"	"
175,000	"	"	"	"	350	"	"	"
180,000	"	"	"	"	360	"	"	"
185,000	"	"	"	"	370	"	"	"
190,000	"	"	"	"	380	"	"	"
195,000	"	"	"	"	390	"	"	"
200,000	"	"	"	"	400	"	"	"
205,000	"	"	"	"	410	"	"	"
210,000	"	"	"	"	420	"	"	"
215,000	"	"	"	"	430	"	"	"
220,000	"	"	"	"	440	"	"	"
225,000	"	"	"	"	450	"	"	"
230,000	"	"	"	"	460	"	"	"
235,000	"	"	"	"	470	"	"	"
240,000	"	"	"	"	480	"	"	"

245,000	cubic	feet	per	hour	=	490	square	inches	area.
250,000	"	"	"	"		500	"	"	"
260,000	"	"	"	"		520	"	"	"
270,000	"	"	"	"		540	"	"	"
280,000	"	"	"	"		560	"	"	"
290,000	"	"	"	"		580	"	"	"
300,000	"	"	"	"		600	"	"	"
310,000	"	"	"	"		620	"	"	"
320,000	"	"	"	"		640	"	"	"
330,000	"	"	"	"		660	"	"	"
340,000	"	"	"	"		680	"	"	"
350,000	"	"	"	"		700	"	"	"
360,000	"	"	"	"		720	"	"	"
370,000	"	"	"	"		740	"	"	"
380,000	"	"	"	"		760	"	"	"
390,000	"	"	"	"		780	"	"	"
400,000	"	"	"	"		800	"	"	"

At 43 feet velocity per second.

(¼-ounce pressure.)

Factor, 1,857,600; no allowance made for friction.

53,750	cubic	feet	per	hour	=	50	square	inches	area.
59,125	"	"	"	"	"	55	"	"	"
64,500	"	"	"	"	"	60	"	"	"
69,875	"	"	"	"	"	65	"	"	"
75,250	"	"	"	"	"	70	"	"	"
86,000	"	"	"	"	"	80	"	"	"
96,750	"	"	"	"	"	90	"	"	"
107,500	"	"	"	"	"	100	"	"	"
118,250	"	"	"	"	"	110	"	"	"
129,000	"	"	"	"	"	120	"	"	"
139,750	"	"	"	"	"	130	"	"	"
150,500	"	"	"	"	"	140	"	"	"
161,250	"	"	"	"	"	150	"	"	"
172,000	"	"	"	"	"	160	"	"	"
182,750	"	"	"	"	"	170	"	"	"
193,500	"	"	"	"	"	180	"	"	"
204,250	"	"	"	"	"	190	"	"	"
215,000	"	"	"	"	"	200	"	"	"
225,750	"	"	"	"	"	210	"	"	"
236,500	"	"	"	"	"	220	"	"	"
247,250	"	"	"	"	"	230	"	"	"

258,000	cubic	feet	per	hour	=	240	square	inches	area.
268,750	“	“	“	“	“	250	“	“	“
279,500	“	“	“	“	“	260	“	“	“
301,000	“	“	“	“	“	280	“	“	“
311,750	“	“	“	“	“	290	“	“	“
322,500	“	“	“	“	“	300	“	“	“
333,050	“	“	“	“	“	310	“	“	“
344,000	“	“	“	“	“	320	“	“	“
365,500	“	“	“	“	“	340	“	“	“
376,250	“	“	“	“	“	350	“	“	“
387,000	“	“	“	“	“	360	“	“	“
397,750	“	“	“	“	“	370	“	“	“
408,500	“	“	“	“	“	380	“	“	“
419,250	“	“	“	“	“	390	“	“	“
430,000	“	“	“	“	“	400	“	“	“
440,750	“	“	“	“	“	410	“	“	“
451,500	“	“	“	“	“	420	“	“	“
462,250	“	“	“	“	“	430	“	“	“
473,000	“	“	“	“	“	440	“	“	“
483,750	“	“	“	“	“	450	“	“	“
494,500	“	“	“	“	“	460	“	“	“
505,250	“	“	“	“	“	470	“	“	“
516,000	“	“	“	“	“	480	“	“	“
526,750	“	“	“	“	“	490	“	“	“
537,500	“	“	“	“	“	500	“	“	“
548,250	“	“	“	“	“	510	“	“	“
559,000	“	“	“	“	“	520	“	“	“
569,750	“	“	“	“	“	530	“	“	“
580,500	“	“	“	“	“	540	“	“	“
591,250	“	“	“	“	“	550	“	“	“
602,000	“	“	“	“	“	560	“	“	“
623,500	“	“	“	“	“	580	“	“	“
645,000	“	“	“	“	“	600	“	“	“
666,100	“	“	“	“	“	620	“	“	“
688,000	“	“	“	“	“	640	“	“	“
709,500	“	“	“	“	“	660	“	“	“
731,000	“	“	“	“	“	680	“	“	“
752,500	“	“	“	“	“	700	“	“	“
774,000	“	“	“	“	“	720	“	“	“
795,500	“	“	“	“	“	740	“	“	“
817,000	“	“	“	“	“	760	“	“	“
838,500	“	“	“	“	“	780	“	“	“

860,000	cubic feet per hour =	800	square iuches area.
881,500	" " " " "	820	" " "
903,000	" " " " "	840	" " "
913,750	" " " " "	850	" " "
924,500	" " " " "	860	" " "
935,250	" " " " "	870	" " "
946,000	" " " " "	880	" " "
956,750	" " " " "	890	" " "
967,500	" " " " "	900	" " "
1,075,000	" " " " "	1,000	" " "

At 60 feet velocity per second.

(½-ounce pressure.)

Factor, 2,592,000; no allowance for friction.

75,000	cubic feet per hour	50	square inches area.
90,000	" " " " "	60	" " "
105,000	" " " " "	70	" " "
120,000	" " " " "	80	" " "
135,000	" " " " "	90	" " "
150,000	" " " " "	100	" " "
165,000	" " " " "	110	" " "
180,000	" " " " "	120	" " "
195,000	" " " " "	130	" " "
210,000	" " " " "	140	" " "
225,000	" " " " "	150	" " "
240,000	" " " " "	160	" " "
255,000	" " " " "	170	" " "
270,000	" " " " "	180	" " "
285,000	" " " " "	190	" " "
300,000	" " " " "	200	" " "
315,000	" " " " "	210	" " "
335,000	" " " " "	220	" " "
345,000	" " " " "	230	" " "
360,000	" " " " "	240	" " "
375,000	" " " " "	250	" " "
390,000	" " " " "	260	" " "
405,000	" " " " "	270	" " "
420,000	" " " " "	280	" " "
435,000	" " " " "	290	" " "
450,000	" " " " "	300	" " "
465,000	" " " " "	310	" " "

480,000	cubic	feet	per	hour	=	320	square	inches	area.
510,000	"	"	"	"	"	340	"	"	"
540,000	"	"	"	"	"	360	"	"	"
570,000	"	"	"	"	"	380	"	"	"
600,000	"	"	"	"	"	400	"	"	"
630,000	"	"	"	"	"	420	"	"	"
670,000	"	"	"	"	"	440	"	"	"
690,000	"	"	"	"	"	460	"	"	"
720,000	"	"	"	"	"	480	"	"	"
750,000	"	"	"	"	"	500	"	"	"
780,000	"	"	"	"	"	520	"	"	"
840,000	"	"	"	"	"	560	"	"	"
900,000	"	"	"	"	"	600	"	"	"
960,000	"	"	"	"	"	640	"	"	"
1,020,000	"	"	"	"	"	680	"	"	"
1,080 000	"	"	"	"	"	720	"	"	"
1,200,000	"	"	"	"	"	800	"	"	"

At 74 feet initial velocity.

($\frac{3}{4}$-oz. pressure.)

Factor, 3,196,800; no allowance for friction.

37,000	cubic	feet	per	hour	=	20	square	inches	area.
74,000	"	"	"	"	"	40	"	"	"
111,000	"	"	"	"	"	60	"	"	"
148,000	"	"	"	"	"	80	"	"	"
185,000	"	"	"	"	"	100	"	"	"
222,000	"	"	"	"	"	120	"	"	"
259,000	"	"	"	"	"	140	"	"	"
296,000	"	"	"	"	"	160	"	"	"
333,000	"	"	"	"	"	180	"	"	"
370,000	"	"	"	"	"	200	"	"	"
407,000	"	"	"	"	"	220	"	"	"
444,000	"	"	"	"	"	240	"	"	"
481,000	"	"	"	"	"	260	"	"	"
518,000	"	"	"	"	"	280	"	"	"
555,000	"	"	"	"	"	300	"	"	"
592,000	"	"	"	"	"	320	"	"	"
629,000	"	"	"	"	"	340	"	"	"
666,000	"	"	"	"	"	360	"	"	"
740,000	"	"	"	"	"	400	"	"	"
814,000	"	"	"	"	"	440	"	"	"

888,000	cubic feet	per	hour	=	480	square	inches	area.
962,000	"	"	"	"	"	520	"	"	"
1,036,000	"	"	"	"	"	560	"	"	"
1,110,000	"	"	"	"	"	600	"	"	"
1,184,000	"	"	"	"	"	640	"	"	"
1,258,000	"	"	"	"	"	680	"	"	"
1,332,000	"	"	"	"	"	720	"	"	"
1,480,000	"	"	"	"	"	800	"	"	"

RULE FOR COMPUTING THE AIR DELIVERY CAPACITY OF PIPES AND FLUES.

Velocity in feet per second × 12 × 3,600 × area of flue or pipe (in inches) ÷ 1,728 = cubic feet capacity per hour.

RULE FOR COMPUTING PIPE AND RISER AREAS FOR HEATING AND VENTILATION WHEN QUANTITY PER PERSON PER HOUR IS THE BASIS.

(No allowance is made for friction.)

Lineal feet of air travel in flue at feet velocity per second.	CUBIC FEET OF AIR SUPPLY PER PERSON PER HOUR.				
	1,000	1,200	1,500	1,800	2,000
5	8.00	9.60	12.00	14.40	16.00
10	4.00	4.80	6.00	7.20	8.00
15	2.66	3.20	4.00	4.80	5.33
20	2.00	2.40	3.00	3.60	4.00
25	1.60	1.94	2.40	2.88	3.20
30	1.33	1.60	2.00	2.40	2.66
35	1.14	1.37	1.71	2.06	2.28
40	1.00	1.20	1.50	1.80	2.00
45	.89	1.06	1.33	1.60	1.78

RULE.—Multiply the tabular number corresponding to the air supply at chosen velocity by the number of persons. The product is the required area of flue in square inches.

Example.—Fifty-two persons in a room at 1,800 cubic feet of air per hour per person; air travel in flue 15 feet per second. Required, the area of flue in square inches.

Tabular number — 1,800 cubic feet at 15 feet per second = 4.80.
4.8 × 52 = 249.6 square inches area of flue.

Memorandum, Subject

FANS.

To the inexperienced a fan *is a fan*, and the result is that the man who uses good logic in presenting claimed merit (regardless of facts) makes impressions which, regardless of merit, gains the end desired — a sale, which too frequently means that the buyer is sold.

Two types of fans are used ; one is known as "disk or ventilator wheels." They deliver the air from the *sides of the vanes* (or blades), are high speed and non-positive in action ; will not deliver $33\frac{1}{3}$ per cent the volume of air claimed. A recent anemometer test applied to a 34-inch ventilator wheel fan running at 711 R. P. M. proved less than 7,000 cubic feet of air per minute was delivered ; the fan is listed by the manufacturers at "20,000 to 25,000 cubic feet." Resistance caused the air to BACK OUT between the ends of the vanes (or blades) and the inclosing shell ; speed of wheel does not overcome that defect.

Disk fans are used for heating and ventilating a portion of the capitol building, Washington, D. C. In a report made by a government heating and ventilating engineer, in May, 1894, I find the following, namely : "The fan should force air into the radiating chambers, but part is thrown back, as indicated by arrows (cut is shown). . . . . the type of fan is not suited for the class of work it has to perform. . . . . Whenever I entered the main cold-air supply tunnel, near the entrance of which this fan

is located, I found in most instances a large bulk of heated air thrown back through the fan into the main air tunnel, which shows conclusively the insufficient power of the fan." (Henry Adams, Heating and Ventilating Engineer, Report No. 853, LIII Congress, second session.)

The other type is known as steel plate exhaust fans, or blowers; the wheels deliver air *from the periphery* and are positive; at

2,584 ft. lineal travel of wheel, periphery will give $\frac{1}{4}$ oz. pressure,
3,657 " " " " " " " $\frac{1}{2}$ " "
4,482 " " " " " " " $\frac{3}{4}$ " "
5,175 " " " " " " " 1 " "

as compared with less than $\frac{1}{4}$ ounce pressure for the ventilator wheel *at 6,278 feet* lineal travel of periphery.

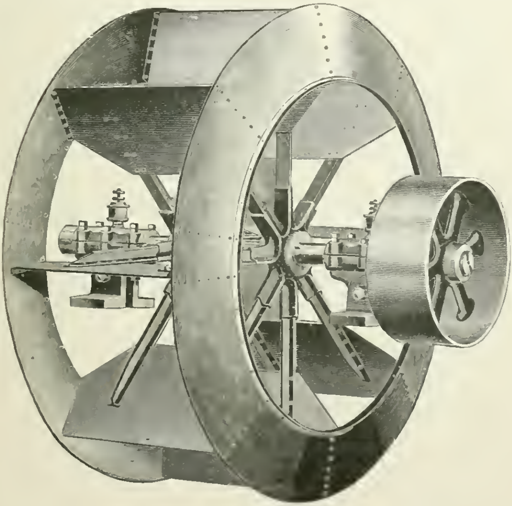


FIG. 3.

Peripheral Discharge Fan Wheel as used in steel plate exhaust fans and blowers.

In mechanical heating and ventilation, fan speed and power must be taken into consideration. In making comparisons the lineal travel of wheel periphery should be the basis.

If 25,000 cubic feet of air per minute shall be required, the bidder who hopes to secure the contract will specify a fan which sells for, say, $700 ; and will require 7 horse-power theoretical ; the bidder who desires to provide the best and most economical plant possible will specify a fan which sells for, say, $1,000, and which will require 2.4 horse-power theoretical ; the latter proponent will be $300 : high in price, but two winters' use will *save, in cost for power*, an equal sum of money.

Owing to lack of knowledge, the $300 difference in price, in nine instances out of ten, settles the matter of award, and the buyer practically throws away $150 every six months the plant shall be operated. The statements of sellers regarding power are not made from a like standpoint, therefore are wholly unreliable for the purpose of comparison ; neither buyer nor architect is competent to analyze and measure the unknown quantities.

It matters not whose standard shall be used, but it is important that *a standard shall be used* it will be alike *just to each competitor.*

Since preparing the preceding matter I have examined a fine public building in Chicago, Illinois ; it cost $1,000,000 ; for heating, in part, and ventilation, the air supply is provided by two steel plate, full-housing fans with wheels 66 inches diameter by 36 inches — 30 inches wide at the periphery — rated by the maker at 49,524 cubic feet capacity each at 300 R. P. M.; the actual capacity is less than 24,000 ; they are operated at about 285 R. P. M., are *insufficient in capacity*, so noisy and expensive for power that they are used only about two hours daily ; the air travel is about 75 feet per second — so high that equalization is impossible.

It is a "misfit," but the seller has been paid.

Properly proportioned, that volume of air can be supplied at 50 feet velocity in main, save seventy-five per cent in power applied — $800 a year — and no noise nuisance.

The criticism is not made as an attack on the system ; the purpose is to correct evils in methods, weed out inexperienced engineers, and teach architects essentials.

The basis for a required volume of ventilation — in a mechanical system—is the *capacity of the fan-wheel to deliver air.* "Capacities" in printed tables are so grossly incorrect that, in defense of truth, I shall "hew to the line, let the chips fall where they may."

"A" listed a fan as follows:

Height of Case.	Wheel Size.	Circumference in Feet.	Blast Area.	Pressure.	Capacity per Minute.	Speed.	H.-P.
140"	84" by 48"	21.99	1176	¼ oz.	21.102	117	2.15
				½ "	29.870	166	6.10
(Peripheral width of wheel is 42".)				¾ "	36.601	204	9.98
				1 "	42.253	230	17.28

In catalogues the capacities were raised to 31.950, 44.320, 55.700 and 62.780 cubic feet. Others who claimed "the only original tables and data," rating fans far above actuals, FORCED *competitors to follow.*

Buyers, comparing capacities and prices, at like prices naturally purchase that rated highest.

"B" lists:

84 by 42 in. wheel, 137 R. P. M., ¼ oz. pres., 35.400 cu. ft. capacity.
" " 189 " ½ " 50.100 " "

At the speeds stated, capacities are 21.098 and 29.106 cubic feet respectively. The revolutions for the stated pressures should be 117 and 166, and true capacities will then be 18.018 and 25.564 cubic feet, respectively.

"C" lists a wheel 84 by 48 inches, as follows:

Speed.	Pressure.	Capacity in cu. ft.	H.-P.
118 R. P. M.	¼ oz.	42.167	2 1
166 " " "	½ "	59.681	5.8
208 " " "	¾ "	73 130	9.5
235 " " "	1 "	84.436	16.5

The true capacities are 21.204, 29.830, 37.376 and 42.229 cubic feet per minute, respectively, provable by "C's" own tables.

"D" lists a wheel 84 inches diameter by 42 inches — 35 inches wide at the periphery:

R. P. M.	Pressure.	Capacity in cu. ft. per minute.
118	¼ oz.	39.638
168	½ "	56.198
209	¾ "	68.753
236	1 "	79.384

That list, corrected, reads:

R. P. M.	Pressure.	Capacity in cu. ft. per minute.
118	¼ oz.	17.688
167	½ "	25.004
204	¾ "	30.544
236	1 "	35.355

The difference in the two tables of capacities is — wind of the maker of the high capacity table.

Pressure is due to velocity; it will be noticed that the speeds and pressures of "A," "C" and "D" ARE ALIKE. The wheel of "A" is TWENTY PER CENT wider than that of "D" at the periphery — in fact, has *twenty per cent greater capacity*, yet "D" CLAIMS *twenty-four per cent larger capacity than "A"* CLAIMS.

The relative difference of the four wheels bases on differences in *widths at the periphery*, all else is *wind* — of the claimants. True, there is a slight difference in the quantity of iron and quality of workmanship.

The height of a fan case, or the size of its discharge, is *not* a basis for capacity; if they are, then one size of wheel would answer for all cases and they might be made ALL MOUTH.

Fan capacities as rated in catalogues are not reliable as a basis for plans and estimates; this is provable by using "the only authentic tables" and the rule of coefficients, and has been proven by anemometrical measurements — which gives the actual volume of air passing through a fan. *The wheel in a fan case is the basis for capacity.* Wheels of like diameters and widths — *at the periphery*—operated at like speeds will deliver like quantities of air. The maker's name, claim, and guarantee adds nothing to capacity.

In the "Introductory" to the "General Catalogue" of "C" you can read . . . "the first comprehensive and authentic tables and diagrams relating to the action of air under pressure and to the speeds, pressures, capacities and powers required upon all classes of blowers were published in our celebrated catalogues of 1870 and 1873." . . . "The information and tables contained therein have formed the basis of all computations upon the movement of air by fans and have been extensively copied, but not originated, by other manufacturers;" . . . "they are here presented as the only authentic tables," and on page 185 . . . "the table upon the succeeding page is, properly speaking, the basis table of all the calculations in this catalogue, giving, as it does, the velocity, number of cubic feet delivered and horse power contained in blast for air under pressure from $\frac{1}{4}$ ounce to 20 ounces." *Note the positiveness of all the matter quoted.*

On page 186 is an elaborate table — "the basis table." For some reason the rules which make the table usable were not put in print. They can be found on page 52 of "Mechanical Heating and Ventilation." That truth shall be demonstrated, I will fit the key to the combination of the lock — "the basis table"— and will use

a fan with wheel 5½ feet by 3 feet; see page 75, catalogue "No. 61."

Example.—The wheel is 66 inches diameter by 36 inches at its center, or widest part, but at the periphery is only 30 inches wide.

1. To find circumference of wheel in feet, $\frac{3.1416 \times 66}{12} = 17.27$ feet circumference of wheel.

RULE 1.—Col. No. 2. $\frac{2584.80}{17.27} = 150$ R.P.M. for ¼ oz. pressure

" " $\frac{3657.60}{17.27} = 212$ " " ½ " "

" " $\frac{4482.00}{17.27} = 259$ " " ¾ " "

" " $\frac{5175.00}{17.27}$ 300 " " 1 " "

RULE 2.—$\frac{66'' \times 30''}{3} = 660$ sq. in. blast area of wheel.

RULE 3.—Col. No. 3. $17.944 \times 660 = 11,843$ cu. ft. per min. capacity

" " $25.400 \times 660 = 16,564$ " " "

" " $31.124 \times 660 = 20,541$ " " "

" " $35.93 \times 660 = 23,713$ " " "

The dividends, "Col. No. 2," and multiplicand, "Col. No. 3," are taken from "the basis table;" the example is the table and rules of "C" applied; the "key" fits the combination for speed, pressure and power, and establishes the fact that "the only authentic tables" *and rule for capacity* have been ignored in rating all fan capacities catalogued.

THE HUYETT FORMULA.

The Huyett rules are more simple, are usable by any person at any speeds and for any sizes of wheels (in that regard they differ from the "only authentic"), are reliable and results are approximately the same as stated in the foregoing.

RULE.—$\frac{3.1416 \times \text{wheel diameter in inches}}{12} =$ circumference of wheel in feet.

2. $\frac{\text{Diameter of wheel in inches} \times \text{width in inches at periphery}}{3}$ = square inches blast area.

3. $\frac{\text{Sq. inches blast area}}{144} =$ square feet blast area of wheel.

4. Circumference of wheel in feet × revolutions per minute × square feet of blast area = capacity in cubic feet per minute.

Example.— Fan with wheel $5\frac{1}{2}$ feet by 3 feet, 30 inches wide at the periphery.

1. $\frac{3.1416 \times 66}{12} = 17.27$ feet circumference of wheel.
2. $\frac{66 \times 30}{3} = 660$ square inches blast area of wheel.
3. $\frac{660}{144} = 4\frac{7}{12}$ square feet blast area of wheel.
4. At 150 R. P. M. $17.27 \times 150 \times 4\frac{7}{12} = 11{,}398$ cu. ft. capacity.
   " 212 R. P. M. $17.27 \times 212 \times 4\frac{7}{12} = 16{,}786$ " "
   " 259 R. P. M. $17.27 \times 259 \times 4\frac{7}{12} = 20{,}501$ " "
   " 300 R. P. M. $17.27 \times 300 \times 4\frac{7}{12} = 23{,}746$ " "

To convince the reader beyond a shadow of doubt with regard to the truth: the wheel has 660 square inches blast area; at 300 revolutions per minute the lineal travel of its periphery is 17.27 feet (circumference) × 300 (R. P. M.) = 5181 feet per minute × 12 (inches) × 660 (square inches blast area) ÷ 1728 (cubic inches per cubic foot) = $23.746\frac{432}{1728}$ cubic feet capacity.

For the fan wheel stated "C" claims—

150 R. P. M.	$\frac{1}{4}$ oz. pressure,	24,734 cu. ft. capacity,	1.2	= H. P.
212 R. P. M.	$\frac{1}{2}$ oz. "	34,992 " "	3.4	= H. P.
259 R. P. M.	$\frac{3}{4}$ oz. "	42,892 " "	5.6	= H. P.
300 R. P. M.	1 oz. "	49,524 " "	9.7	= H. P.

and claims in like proportion for other sizes of wheels. Unless air will travel through a fan wheel faster than the lineal travel of its periphery — the part which gives it motion — it is a physical impossibility to secure air volumes in excess of those stated in the application of "Rule 3," or as shown by "4" in the Huyett formula. If air *will travel faster* than the peripheral travel of wheel the claimants have discovered *perpetual motion.*

One manufacturer *raised* capacities 60 to 75 per cent *without increasing speed and power*, and this notwithstanding the fact that its own tables show that an increase of *100 per cent* in capacity increases the power required *800 per cent.*

ESTIMATING FAN POWER REQUIRED.

For $\frac{1}{4}$ oz. pressure, .001224 × 1.5 × sq. in. blast area × 2 = H. P.
" $\frac{1}{2}$ oz. " .003463 × 1.5 × sq. in. blast area × 2 = H. P.
" $\frac{3}{4}$ oz. " .005659 × 1.5 × sq. in. blast area × 2 = H. P.
" 1 oz. " .0098 × 1.5 × sq. in. blast area × 2 = H. P.

Example.— Wheel $5\frac{1}{2}$ by 3 feet, at 300 R. P. M. .0098 × 1.5 = .1470 × 660 × 2 = 1940400 or 19.4 H. P.

If the reader will refer to catalogue of "C," No. 61, page 75, that wheel will be found rated at 9.7 H. P., at 300 R. P. M. = 19.4 H. P. for two. Recently disinterested experts measured the power required for two such fans, one at 285 and the other at 277 R. P. M.; the combined power required was 31.5 H. P. At the speeds stated anemometrical measurements showed less than 45,000 cubic feet air delivery; they are rated 99,048 cubic feet at 300 R. P. M.

The immortal Lincoln in a speech stated, "It is possible to fool all people sometime, it is possible to fool all people one time, but it is not possible to fool all people all the time."

If people *continue to be fooled* with regard to fan capacities and powers it will be *their own fault*. The following are standard sizes of fans, wheels, blast areas, pressures, speeds, capacities and powers; they are reliable. It is the first authentic data put in print and should be accepted as the basis for general engineering practice.

No two manufacturers agree on all the details; each claims to "know all about the business," and in the shape of fans have "the only." The general principle, coefficients, *is alike in all makes;* the main difference is in wheel dimensions. Fans of extreme width at the periphery have been taken, and it is safe to state that *all other makes operated at like pressures deliver less quantities of air*, in proportion as wheels are narrower at the periphery, some ranging down 20 per cent.

The following table is inserted as a convenience for the reader; the computations for capacity are based on the table of coefficients to be found on pages 46 and 47. It gives factors which are not shown by the table referred to (coefficients), including theoretical and actual H. P. as determined by recent measurements.

Memorandum, Subject

STANDARD RATINGS FOR FANS.

Based on the standard dimensions of a reliable manufacturer. Capacity is based on coefficients.

Case Height in inches.	Wheel Diameters, with Peripheral Widths.	Wheel Circumference in feet.	Square inches Blast Area.	Speeds. R. P. M.	Pressure in ounces.	Capacity in cubic feet per minute.	H. P. Theoretical.	Actual H. P.
60″	38 x 14″	9.94′	177	260	¼	3,175	.32	.64
				368	½	4,512	.91	1.82
				451	¾	5,497	1.5	3.
				520	1	6,350	2.6	5.2
70″	42 x 17½″	10.99′	245	235	¼	4,400	.44	.88
				333	½	6,248	1.27	2.54
				408	¾	7,657	2.07	4.14
				473	1	8,597	3.6	7.20
80″	48 x 20″	12.56′	320	206	¼	5,768	.58	1.16
				291	½	8,148	1.66	3.32
				357	¾	9,995	2.71	5.42
				412	1	11,536	4.70	9.40
90″	54 x 24″	14.13′	432	183	¼	7,741	.79	1.58
				258	½	10,913	2.24	4.48
				317	¾	13,409	3.66	7.32
				366	1	15,481	6.35	12.70
100″	60 x 26″	15.70′	520	165	¼	9,339	.94	1.88
				233	½	13,187	2.70	5.40
				285	¾	16,131	4.41	8.82
				329	1	18,621	7.64	15.28
110″	66 x 30″	17.27′	660	144	¼	11,404	1.21	2.42
				212	½	16,786	3.42	6.84
				259	¾	20,513	5.60	11.20
				300	1	23,760	9.70	19.40
120″	72 x 33″	18.85′	792	137	¼	14,203	1.41	2.82
				194	½	20,058	4.11	8.22
				260	¾	26,946	6.72	13.44
				274	1	28,400	11.64	23.28
140″	84 x 42″	21.99′	1176	117	¼	21,115	2.15	4.30
				166	½	29,841	6.10	12.20
				204	¾	36,659	9.98	19.96
				236	1	42,409	17.28	34.56
160″	96 x 45″	25.13′	1440	103	¼	25,884	2.42	4.84
				145	½	36,438	7.48	14.96
				179	¾	44,982	12.22	24.44
				206	1	51,516	21.16	42.32

Notice the fact that if 11,500 cubic feet of air per minute shall be required an 80-inch fan will do the work with 9.4 H. P. applied; a 110-inch fan will provide like results with 2.4 H. P.; the difference is 7 H. P.— equivalent to a saving amounting to $350 to

$400 a year; the smaller fan lessens the first cost of plant $100 to $200. But buyers reason, "the smaller fan performs like duty as the larger one hence it must be a better one. . . . . The agent so claims and proves (?) capacity by showing the tables in the catalogue." That usually settles it. In general a large fan at low speed will deliver a like quantity of air with more economy than a small fan at higher speed.

Memorandum, Subject

THE HUYETT TABLE OF FAN WHEEL CAPACITY COEFFICIENTS. (See Rule.)

Outside Dia. of Wheel. (In Inches.)	WIDTH OF WHEEL AT PERIPHERY (IN INCHES).																					
	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
36	14.1	15.7	17.3	18.8	20.4	22.0	23.6	25.1	26.7	28.2												
38	15.7	17.5	19.2	21.0	22.8	24.5	26.3	28.0	29.8	31.5	33.2	**40**										
40	17.5	19.4	21.4	23.3	25.2	27.2	29.1	31.0	33.0	34.9	36.9	38.8	**42**									
42	19.3	21.4	23.6	25.7	27.8	30.0	32.1	34.2	36.4	38.5	40.7	42.8	45.0	**44**								
44	21.1	23.4	25.8	28.2	30.5	32.8	35.2	37.5	39.9	42.2	44.6	47.0	49.3	51.6	**46**							
46	23.0	25.6	28.2	30.7	33.3	35.8	38.4	41.0	43.5	46.1	48.6	51.2	53.8	56.4	59.0	**48**						
48	25.2	28.0	30.8	33.5	36.3	39.1	41.9	44.7	47.5	50.2	53.1	55.9	58.7	61.5	64.2	67.[illegible]	**50**					
50	27.3	30.3	33.3	36.4	39.4	42.4	45.5	48.5	51.5	54.5	57.5	60.6	63.6	66.6	69.6	72.7	75.7	**52**				
52	29.5	32.8	36.1	39.3	42.6	45.9	49.2	52.5	55.8	[illegible]9.0	62.3	65.6	68.9	72.2	75.4	78.7	82.0	85.2	**54**			
54	31.8	35.3	38.8	42.3	45.8	49.4	53.0	56.5	60.0	63.5	67.1	70.6	74.2	77.7	81.2	84.7	88.2	91.8	95.4	**56**		
56	**18**	38.0	41.7	45.6	49.4	53.2	57.0	60.7	64.5	68.3	72.1	76.0	79.8	83.5	87.3	91.1	95.0	98.7	102.6	106.5	**58**	
58		40.8	44.9	48.9	53.0	57.1	61.2	65.2	69.3	73.4	77.5	81.6	85.6	89.7	93.8	97.9	102.0	106.0	110.1	114.1	118.2	**60**
60		43.6	48.0	52.3	56.6	61.0	65.4	69.8	74.1	78.5	82.8	87.2	91.5	96.0	100.0	104.6	109.0	113.3	117.8	122.0	126.5	131.0
62		**20**	51.3	55.9	60.6	65.2	69.9	74.5	79.2	83.9	88.5	93.1	97.7	102.5	107.1	111.8	116.4	121.0	125.8	130.4	135.0	139.6
64			54.5	59.5	64.5	69.5	74.5	79.5	84.5	89.4	94.3	99.2	104.2	109.1	114.0	119.0	124.0	129.0	134.0	139.0	144.0	149.[illegible]
66			58.2	63.4	68.6	73.9	79.2	84.5	89.7	95.0	100.0	105.5	111.0	116.2	121.3	126.6	132.0	137.2	142.5	147.6	153.0	158.3

68	**22**	67.2	72.9	78.5	84.0	89.6	95.2	100.8	106.4	112.0	117.6	123.2	128.7	134.4	140.0	145.5	151.1	156.8	162.4	168.0
70		71.3	77.2	83.2	89.2	95.0	101.0	106.9	112.9	118.8	124.7	130.6	136.5	142.5	148.5	154.5	160.4	166.3	172.1	178.1
72		75.3	81.6	87.9	94.2	100.5	106.7	113.0	119.3	125.6	131.9	138.1	144.4	150.6	157.0	163.3	169.5	175.8	182.1	188.4
74		**24**	86.2	92.8	99.5	106.0	112.6	119.3	126.0	132.5	139.1	145.8	152.5	159.0	165.7	172.3	179.0	185.6	192.3	199.0
76			91.0	98.0	105.0	112.0	119.0	126.0	133.0	140.0	147.0	154.0	161.0	168.0	175.0	182.0	189.0	196.0	203.0	210.0
78			96.0	103.1	110.6	118.0	125.3	132.8	140.1	147.5	155.0	162.3	169.6	177.0	184.3	191.6	199.0	206.4	214.0	221.4
80			**26**	108.6	116.4	124.1	132.0	139.6	147.5	155.2	163.0	170.7	178.5	186.2	194.0	202.0	209.6	217.3	225.0	233.0
82				114.2	122.4	130.5	138.6	146.8	155.0	163.2	171.4	179.5	187.8	196.0	204.0	212.2	220.2	228.4	236.6	245.0
84				119.8	128.3	136.8	145.5	154.0	162.6	171.1	179.7	188.2	196.8	205.3	214.0	222.5	231.0	239.5	248.0	256.5
86				**28**	134.3	143.2	152.1	161.1	170.1	179.0	188.0	197.0	206.0	215.0	224.0	233.0	242.0	251.0	260.0	269.0
88					140.5	150.0	159.3	168.7	178.1	187.5	96.8	206.1	215.5	225.0	234.3	243.6	253.0	262.2	272.0	281.0
90					147.0	156.6	166.5	[illegible]	186.3	196.0	206.0	215.8	225.8	235.5	245.0	255.0	264.6	274.3	284.0	294.0
92					**30**	164.1	174.5	184.6	195.0	205.0	215.5	225.8	236.0	246.2	256.3	266.4	277.0	287.0	297.5	308.0
94						171.0	182.0	192.5	203.5	214.0	224.4	235.4	246.0	256.6	267.5	278.0	289.0	299.5	310.0	321.0
96						178.8	190.0	201.0	212.3	223.6	234.6	246.0	257.0	268.2	279.6	290.3	302.0	313.0	324.0	335.0
98						**32**	198.3	210.0	222.0	233.5	245.0	256.5	268.0	280.0	292.0	303.5	315.0	327.0	338.0	350.0
100							206.0	218.0	230.0	242.5	254.5	266.6	278.8	291.0	303.0	315.0	327.0	339.5	351.5	364.0
102							214.4	227.0	240.0	252.4	265.0	277.5	290.0	303.0	315.5	328.0	341.0	353.0	366.0	378.5
104							**34**	236.0	249.2	262.4	275.5	288.6	302.0	315.0	328.0	341.0	354.0	367.0	380.0	394.0
106								247.5	259.0	272.5	286.5	300.0	313.5	327.0	341.0	354.5	368.0	382.0	395.0	408.0
108								255.0	269.0	283.0	297.5	311.5	326.0	340.0	354.0	368.0	382.0	396.5	411.0	425.0

Given size of fan wheel and R. P. M. to find capacity.

RULE.—Find number from table for wheel of given diameter and width. Multiply this tabular number by the given number of revolutions per minute. The product is the "free" capacity of fan wheel in cubic feet per minute.

RULE 11.— Given, capacity of fan required. To find sizes of wheels that will give this required capacity at chosen R. P. M. Divide the capacity of fan (in cubic feet per minute) by the speed (in R. P. M.), the quotient is the tabular numbers corresponding to wheel of diameter and width; width fixed by the position of this number.

Example.—Capacity required 20,000 cubic feet per minute, speed of wheel 100 R. P. M.; $\frac{20,000}{100} = 200$, the table number.

200 (206) wheel 100 inches by 34 inches,
(201) " 96 " " 36 "
(203.5) " 94 " " 38 "
(206) " 90 " " 42 " or wherever the number shall be found.

The reader who shall have patiently studied this exhaustive analysis will comprehend that the author has not "extensively copied" "the only authentic tables" . . . which no reader or student has ever been able to use.

Wheel sizes listed in all catalogues are widths at centers. A "7 by 4 feet wheel" leads the inexperienced to believe it is 7 feet in diameter by 4 feet wide; true, it is that wide at the center, but at the periphery, the basis for capacity, it is 35 inches to 42 inches, depending on who makes it.

COMPARATIVE CLAIMS.

"A" claims a wheel	66 x 30"	at periphery	at 299	R.P.M.	= 36,155	cu. ft	capacity
"B" " "	67 x 27½"	"	" 300	"	= 42,840	" "	"
"C" " "	66 x 30"	"	" 300	"	= 49,524	" "	"
"D" " "	66 x 28"	"	" 300	"	= 50,508	" "	"

On the basis of *proportional claim* the latter is overrated 8,019 cubic feet, and on the basis of *proportional fact is overrated 28,376 cubic feet*, approximately.

Persons may claim, but facts are stubborn things.

Memorandum, Subject

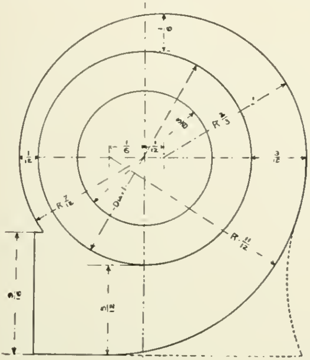


FIG. 4.
Diagram of Fan Proportions.

The fan wheel is the basis of all figures.

Unit = diameter of wheel (twelve twelfths) = 1; i. e. all figures are parts of the wheel, viz., $\frac{9}{16}$ of wheel diameter = height of mouth.

Inlet $\frac{5}{8}$ diameter of wheel.

Width of housing is $\frac{6}{12}$ for wide wheels and $\frac{3}{8}$ for narrow wheels.

A close approximation to the actual curves may be obtained by taking centers and radii as indicated by dotted lines and figures; each are started from horizontal center lines.

Width of case (in inches) equals the width of wheel (in inches) at outlet + the pitch of the sides of the wheel ($\frac{1}{24}$ of diameter of wheel in inches on each side) + clearance of wheel between the inlet rings of the wheel and the fan case = inside width of outlet of fan case.

Memorandum, Subject

CAUTIONING.

Architects should require, in specifications, height of fan case — approximate — diameter of fan wheel, width of fan wheel at its periphery, number of revolutions per minute to be operated at, and cubic feet air delivery at the designated speed, and reject specifications as being incomplete which do not contain those essentials — they are just as essential as is the full specifications for boilers and their settings.

In mechanical heating and ventilation, heat — force — is not applied by means of direct radiation or by vertical risers connecting from indirects, hence the fan is a most essential element and requires more than casual notice. Fan, heater and motor have been located in basements to heat nine floors above; on third floor and on a sixth floor, to take air supply from above the roof line and warm all the space below, and in a separated boiler room located seventy feet from a three-story building 340 by 45 feet; it matters not what the location, the warmed-air delivery and volume of ventilation depends on the fan.

Contracts for heating and ventilating apparatus are too frequently let to the "lowest bidder," regardless of the factors of safety, efficiency, sufficiency, durability and economy; in submitting proposals each bidder makes his own plans and specifications, not two are alike, and no one — other than an expert — can analyze and determine which is the cheapest and safest.

It is a simple matter to reduce the factors of safety, durability and economy, *and thereby reduce the cost.*

Recently there was sharp competition for the apparatus for a large church building; one proposal stated specifically the sizes, quantities, etc., and forced others to be like specific. "He dies hard," was the remark of the person who represented the firm that secured the contract. Knowing the business methods of the successful representative's firm, "the corpse" fastened a petard where its subsequent explosion damaged a tattooed reputation, caused loss, and SAVED THE BUYER FROM BEING VICTIMIZED; the heater was measured and found short 1,000 feet of pipe, the fan was "sized up" and found under the specifications; the shortage on pipe was made good — under compulsion — the fan was shipped back to the factory and one of the proper size was forwarded; the amount attempted to be "saved" WAS ENOUGH TO GET UNDER THE HONEST BIDDER'S PRICE. It was a DELIBERATE ATTEMPT TO BEAT THE PURCHASER, the ignorance of buyers was relied upon for success, but the petard exploded — "they did not know it was loaded."

Buyers of wheat, coal, iron, and products bought and sold by weight, WEIGH *the material delivered*, and other products are measured by the usual commercial standards, but buyers of heating apparatus take that sent them, and not one in one hundred KNOWS if or not quantities are received as specified. "What fools these mortals be." The hint should be sufficient.

"Feet capacity heaters" and "heater to contain —— feet of 1-inch steel pipe" *are not* synonymous terms descriptive of like quantities, the former is a "trick of the trade" favorable to the seller to the extent of five to ten per cent.

Any seller who fails to specify the actual quantity of 1-inch steam pipe, diameter of fan wheel and its width at the periphery, R. P. M. and speed of engine, *does so with the intent to get a contract that shall be* DEFINITELY INDEFINITE — except they hedge behind "we are responsible" and "we guarantee." Responsibility and guarantee *never yet warmed and ventilated a building*, that requires a *definite quantity of steam pipe and volume of air contact therewith.*

Another "trick of the trade" is to get specifications shaped for "the Jones [or some other] system," *the intent of that is to lessen the force of competition.* Mechanical heating and ventilation is the SAME SYSTEM, practically, *regardless of who manufactures the apparatus*, but there *is a difference* in the engineering experience which forms the detail plan and combinations; no one

firm owns or has a mortgage on all the engineering ability in the United States.

Another "trick of the trade" is claimed fan "*capacities*"; the claims will be found analyzed elsewhere — see Tables A, B, C, D. The corrected tables are the claimants' basis with the *wind squeezed out*.

BOSTON

RULES FOR CALCULATING PRESSURES, SPEEDS, CAPACITY AND POWERS FOR BLOWERS AND EXHAUSTERS.

1.— Column No. 2, divided by circumference of wheel in feet, equals R. P. M. necessary to sustain the pressure opposite in column No. 1.

2.— Diameter of wheel, in inches, multiplied by its width at the periphery, in inches, and divided by 3, equals square inches blast area.

3.— Column No. 3, multiplied by area of blast in square inches, gives capacity in cubic feet of air per minute.

4.— Column No. 4, multiplied by 1½ and multiplied by the area of blast in square inches, gives theoretical H. P.

Fans are such an important factor in heating and ventilation that all honest interested parties should be willing to adopt a fixed standard for capacity (architects can force it).

The "key"— Rules 1 to 4, inclusive — and the "lock" were made by one of the most capable engineers in the United States. I would be willing to accept that basis but for the fact that between the speeds for different pressures there is too much of the unknown quantity — except for experts. Any reader who desires the "lock" should write to M. C. Huyett, heating and ventilating engineer, Monadnock building, Chicago, Illinois.

The lock and key are essential for *speeds and pressures*, but for capacity "The Huyett Rule" is more readily used, at any speed.

This exhaustive analysis of fans is made for the purpose of squeezing the wind out of claims and instructing architects so they shall be able to measure each fan specified by a *like standard*, in order to be able to judge relative capacity on the basis of fact, protect clients and force competitions to a legitimate basis.

1	2	3	4	5	6
1	[illegible]	17.941	0.001224	14662.76	817.00
[illegible]	3657.60	25.400	0.003463	7333.70	288.70
[illegible]	[illegible]	31.121	0.005655	1889.11	157.08
[illegible]	[illegible]	[illegible]	0.0098	3666.62	102.05
[illegible]	[illegible]	[illegible]	0.0278	1833.00	55.970
[illegible]	[illegible]	[illegible]	0.0512	1222.30	19.510
[illegible]	[illegible]	72.37	[illegible]	916.27	12.660
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.045
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.867

pipe leading from the receiver to outer air. When water shall be

MOTORS.

In mechanical heating and ventilation, power of some kind must be provided for operating the fan. First cost of plant can be kept lowest by installing a steam engine; when this kind of power shall be used for fan propulsion in schools, churches and other public buildings, the steam cylinder should be of sufficient area to develop the required amount of power with steam pressure on the boiler at from fifteen to twenty pounds, with ordinary lineal travel of piston.

The horizontal type of engine, self-contained, with disk crank, is easiest to keep in adjustment; they should have an automatic stop variable speed governor, throttle valve, sight feed lubricator, governor belt, oil cups and wrenches.

An "automatic cut-off" is no advantage; the load is, practically, nonshifting.

Engines should be installed on substantial masonry foundations, built separate from other foundations or walls, if practicable.

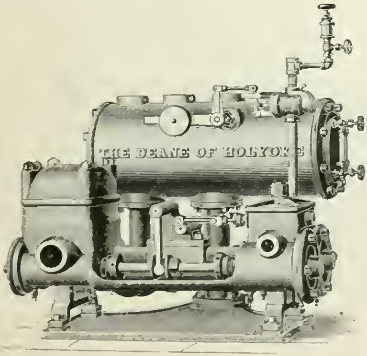


Fig. 5.
Automatic Pump and Receiver.

When heating is required, a steam motor is next the cheapest power; the steam used for power should be used for heat production, and water—the result of condensation in the heater—be returned to the boiler, automatically, with the latent heat contained therein. Necessarily there will be some loss of water, from the boiler, due to the escape of vapor through the vapor pipe leading from the receiver to outer air. When water shall be so returned it is an element of danger, because of cylinder oil making the water in the boiler liable to foam, and the additional liability of the boiler to be blistered or burned—either being simply

a question of time; therefore an oil separator *is indispensable*, and should be placed in the exhaust pipe and preferably near the engine; this makes the application absolutely safe as regards the elements of danger stated.

Belt or rope transmission of power will prove most satisfactory and should invariably be used, except where space is too limited to get length of belt.

Electric motors are safe, convenient, controllable, and are usable for heating with lower steam pressure on a boiler than is possible when a steam engine is used, and can be used for providing ventilation when no steam for heat (no fire under boiler) shall be required.

Water Motors are simple and safe; their use is practicable where high water pressures are maintained.

Gas and Gasoline Engines.—The latter *is the cheapest power known;* when properly installed it is absolutely safe, is controllable, and when a proper "muffler" is used they are practically

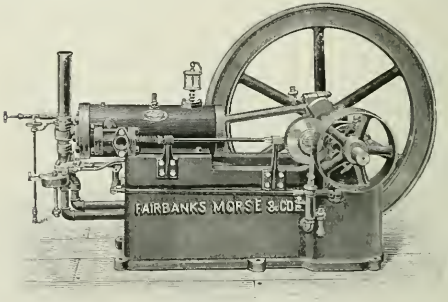


FIG. 6.—Gas and Gasoline Engine.

noiseless; their use makes ventilation possible without fire under the boiler when no heat shall be required. When they are used ALL *water*, the result of condensation in the heater, should be returned to the boiler automatically, thus saving the latent heat contained therein.

The cost for power can be based on $\frac{1}{10}$ gallon of gasoline per horse-power per hour.

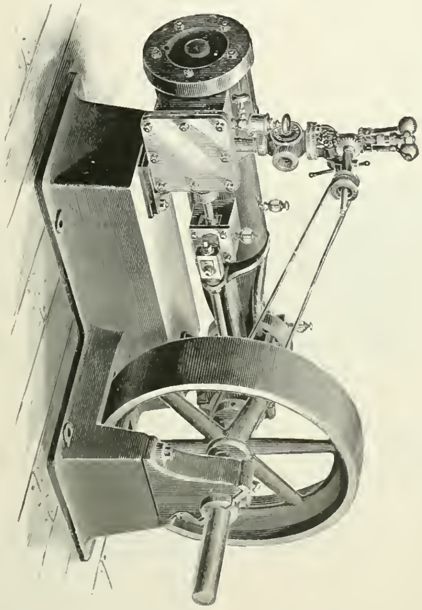


FIG. 7.—Horizontal Engine—Self-contained.

Either of the latter three motors simplifies apparatus, increases safety factors, and adds to life of boiler and efficiency of apparatus.

PUMP AND RECEIVERS.

Installations of heaters can rarely be made so as to secure "gravity return" of water, the result of condensation; when that is impossible intermediary mechanisms must be installed between the heater and the boiler. That illustrated in Fig. 5 is automatic, and with water-supply connection can be used for "boiler feed."

STEAM TRAPS.

Where a steam engine is used for power economy is best secured by placing an oil separator between the engine and heater so that water, the result of condensation, may safely be used time and time again and be fed back to the boiler with all the heat contained therein. Where such an application is made a part of the heater must be used with live steam, which necessitates that either the condensation of exhaust steam shall be wasted—with the heat force contained therein—or a steam trap, or traps, be installed in order that the part of the heater using live steam shall not be wasteful. The condensation from both should drain into a receiving tank, which, of necessity, must have an opening to the atmosphere. If the two parts of the heater shall drain to the receiving tank of an automatic pump the flow from the part of the heater using exhaust steam will be slow but constant while that from steam traps, as ordinarily used, will be inconstant and powerful at the times of discharge; consequently the pump governor will open quickly and operate the pump with great rapidity for a short time, and then slow down to the nor-

FIG. 8.
Pot Trap.

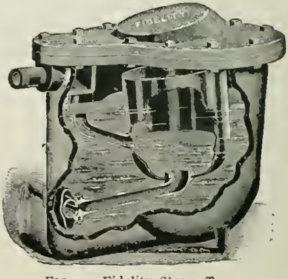


FIG. 9.—Fidelity Steam Trap.

mal speed; such an application results in discharge of water through the pipe which leads to atmosphere. I have known the water to be thrown 50 feet high under such conditions.

For cheapness of construction the ordinary "pot trap" is used. (See Fig. 8.) It is difficult to adjust, discharges spasmodically, and to be economical requires frequent cleansing.

Where such an installation is required the trap used should be of a kind which discharges constantly, i. e., the flow of water therefrom be in proportion to the inflow thereto. For the purpose of discharging water from high pressure parts of heaters to the receiving tank of automatic pumps the type of trap as shown by Fig. 9 is recommended; its construction is such that water entering the inlet opening "A" is diverted and forced into the body of the trap exterior to the float; all sediment falls to the bottom of the receptacle which contains the float and valve, water flows into the float in proportion to the volume and as the float rises or falls it opens the valve proportionally for the outflow of water.

It should be noticed that the valve is inclosed so that sediment remains in the receptacle and it may be discharged therefrom by opening a valve placed at the base of the receptacle, thus *blowing it out*. This discharge should connect with sewer or "blow-off pipe."

In large installations where heaters are constructed usable in different parts, that part with which air to be warmed shall have first contact becomes the low pressure part of the heater, hence, if a heater is constructed to be usable in, say, three parts, that part with which air shall have first contact should have a separate trap for the reason that high pressure and low pressure connections to the same trap will not drain the low pressure part of the heater properly, the high pressure holding back the water in the low pressure part of the heater; true this will not always obtain, because conditions are not always alike.

Pot traps should not be accepted as part of a first-class plant.

HEATERS.

Heaters are efficient in proportion to the equalization of *steam pressure in the pipes and air contact with their surfaces* radiating surface.

Three types of heaters are in common use: one is the ordinary "box coil" construction; a second type is with pipes mounted part vertical and part horizontal, with each loop differing, in length of the three pieces of pipe, from that of any other loop in the

same row in the section, and are made up with four rows of pipes to each section ; the third type is made with two rows of pipes in each section. The claim made for the box coil heater — that "horizontal steam pipes will deliver more heat units than vertical

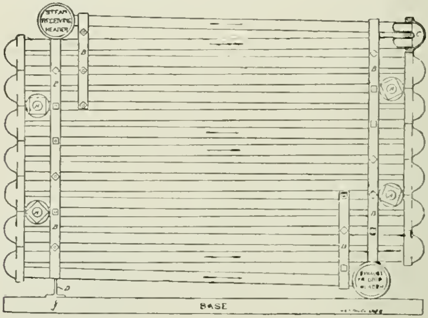


FIG. 10.
Box Coil Heater.

ones" will be true when a *natural circulation gives air contact*, but is not true when air is forced against the pipes by a fan. Air will always travel in a straight line when possible, and will follow the lines of least resistance. In box coil constructions the pipes are *not staggered* and the lines of least resistance *are between the pipes*, hence, air is not divided and subdivided and does not have contact with the radiating surface to the same extent as in staggered pipe heaters. For this reason that type of heater requires about fifty per cent more pipe than other heaters for like duty.

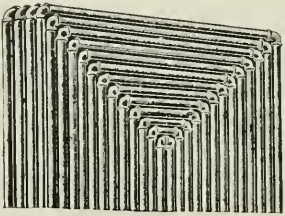


FIG. 11.
Showing the four-row pipe construction in common use.

Those of the second type, used by two or three manufacturers, are alike, the only difference being in the manifolding. Fig. 11 shows the general construction.

The third type is shown in Fig. 12. The pipes are all of equal lengths and are made up in sectional bases with two rows of pipes in each section. The general principle in this construction is the same as that in the heater designed in 1884, by M. C. Huyett. It has stood the test of ten years' use. Many of the heaters

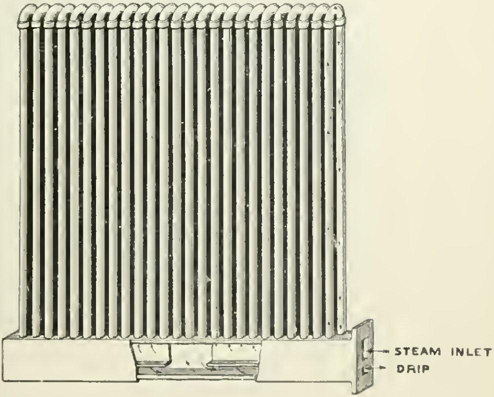


FIG. 12.
Huyett's Improved Heater section, with two rows of pipes.

have been used day and night more than three hundred days per year during that time, and *without repairs.* The only improvement possible has been the abandonment of the "lock nut nipples" used to connect each end of the sections to manifolds and substituting flanged connections (to connect to one manifold) at one end of the sections only.

The sections are grouped in such manner that one, two or three parts of a heater can be used at will ; this gives complete control of the initial temperature without increasing or decreasing steam pressure. The staggered arrangement of the pipes causes the air

in its passage through the heater to be divided and subdivided and have contact with the radiating surfaces as many times as there are rows of pipe -- from front to rear of heater — regardless of the temperature of the radiating surfaces, the pressure of contact being in proportion to the air velocity

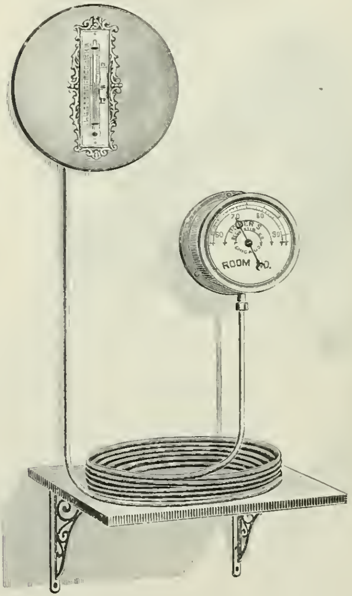


FIG. 13.

Powers' Telethermometer. Thermometer in a room, and the indicator at any required distance, where engineer can read room temperature.

The completed heater is inclosed in a steel jacket in the customary manner, one end being open for the admission of air to be warmed, and the opposite end connected to the fan inlet; this

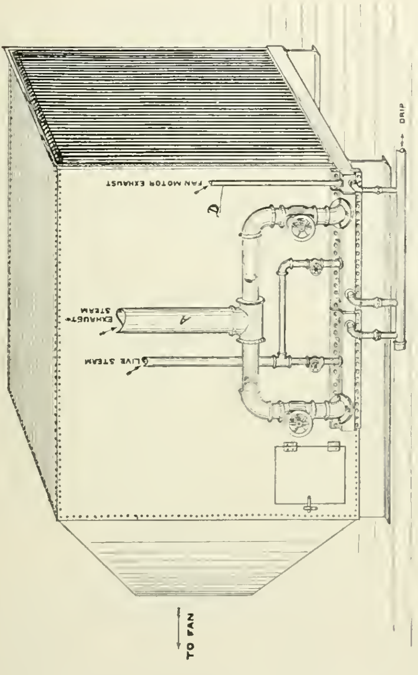


FIG. 14.
Huyett's Improved Heater complete, encased in steel jacket.

provides apparatus for *exhausting* the air through the heater so that the fan handles the heated product.

It is true that heaters are installed with fans to deliver cold air and force it in contact with the radiating surfaces; when that is

done the fan must overcome the friction of air in ventilating ducts, plus the resistance of air at rest in rooms to be warmed and ventilated, plus friction of air in the hot-air distributing pipes leading from the heater to the rooms, plus the resistance caused by a mass of pipes located immediately at the discharge opening of the fan. That kind of an application requires higher speed of fan, increases the power required, and adds to the cost of operating; in addition waste oil from journal bearings drains into the fan wheel and is thrown therefrom in contact with hot radiating surfaces upon which dust gathers, making, in time, unhealthful conditions, reducing efficiency, and causing a constantly increasing fire risk. It is claimed that "by blowing air across the radiating surfaces an increase in volume due to expansion is secured." The claim is plausible, but not truthful; that element never forms a part of the mathematical calculation in making up estimates for heating and ventilating air volumes. Volume of air for heating and ventilation is based on lineal travel in air-distributing pipes and through openings therefrom to rooms, and a definite required quantity forms part of the calculation; if *expansion* shall be depended upon for volume the *quantity will be inconstant* because of the difference in heat force required to provide sufficient heating under the varying conditions of external temperatures.

A given volume of air, only, can be forced through a given sized pipe, or flue, at a given velocity (velocity is the basis of all calculations); "air expansion" *never* enters into calculations, it is too infinitesimally small a factor upon which to base an argument.

With a fan *exhausting* across a heater it must overcome all of the factors stated in the first part of a foregoing paragraph except the resistance of the mass of pipes at the fan discharge; with this application atmospheric pressure forces the air through the heater in contact with its radiating surface and insures a more equal contact and higher efficiency of apparatus.

The third paragraph preceding refers to applications *as ordinarily made*; when space will admit of distance between the fan wheel and the radiators, such as will admit of reducing velocities at least fifty per cent and equalizing pressure, radiating surfaces can be spread out so that the air contact will be at low velocities and make applications with fan blowing air through heaters possible. Fig. 14 shows a heater arranged, complete, for using live or exhaust steam, and the fan to exhaust the air through the heater; as applied in church and school buildings the steam pipe "A" with its connections "B" "C" are omitted, that feature being

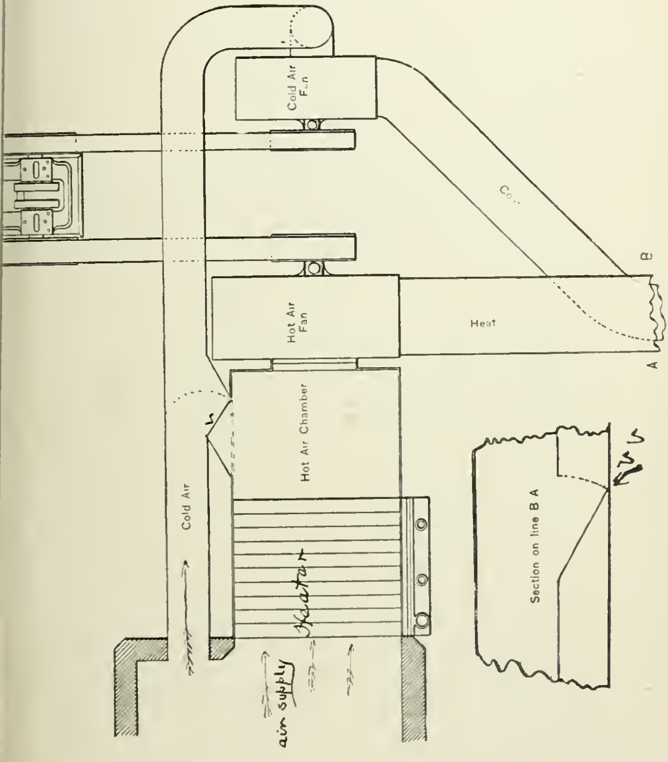


FIG. 15.
A two-pipe system with two separate fans or a duplex fan. Designed by M. C. Huyett

essential only where exhaust steam is obtainable in addition to that of the motor (if steam engine) used to operate the fan.

Fig. 15 shows an air-supply chamber—or exterior to the heater room — heater, air chamber, hot-air fan, and cold-air fan. Air is exhausted through the heater by the hot-air fan and delivered to heat risers through one set of ducts while the cold-air fan takes its supply by the heater without contact and delivers it through a separate set of ducts to the bases of the heat risers, where its flow shall be controlled by automatic damper regulation. If the cold air requires "tempering" the result is secured by using valve V, which will shut off part of the cold air and admit a proportional quantity of hot air from the "air chamber." When first warming shall be required (or additional heat power is required to meet an emergency), the entire cold-air supply can be shut off and valve "V V" be opened so that the two fans will be operative for the delivery of hot air; the capacity of the cold-air fan to that for hot air being as 1 is to 2, the heat-producing power of the plant will be increased nearly fifty per cent without increasing the speed of motor. The argument will be made that "the two fans will require more power than if one be used." If the hot-air fan be proportioned to supply the required volume of air and automatic heat regulation be used, while the air in the rooms to be warmed shall be below the temperature at which the thermostats be set at for control, the openings from the cold-air pipes to the heat risers *will remain closed* and the cold-air fan will revolve the air in the fan case. The only power it will use will be that to compensate for journal friction and the friction of air in the fan case; when the point at which the thermostats are set to become operative has been reached the cold-air valves will open partially and shut off the supply of hot air proportionally, with the result that the cold-air fan begins to require power — in proportion to the air deliveries, and the hot-air fan will require less power — in proportion as it shall be delivering less air volumes.

At times when both fans shall be used with air volumes and heat power cumulated through the hot-air pipe system the power required will be increased fifty per cent; the volume will be increased, but the power required will be less than if a like quantity of air be delivered by increasing the speed of the hot-air fan only.

After first warming, or the emergency passes, the valve V V should be changed to the regular basis, i. e., so that the cold-air fan shall deliver cold air to the base of the heat risers.

COMBINATION OF HOT-BLAST SYSTEM AND DIRECT RADIATION.

In the application of mechanical heating and ventilating apparatus to church buildings the addition of direct radiation should be made in pastor's room, vestibule to chapel and parlor, and in school buildings in office and toilet rooms; these radiators not as factors for warming but to maintain temperature or make warming possible at times when the fan system shall not be in operation.

The return of water, the result of condensation, to the boiler can ordinarily be made gravity system, but inasmuch as a pump and receiver — with automatic governor — must be provided for in the general installation, the best application possible will be to connect therewith with a by-pass, in order that the return of water may be secured either by gravity or by pump at will.

Gravity return is impracticable where reducing-pressure valves are used.

AIR-DISTRIBUTING DUCTS.

Air ducts should be made of galvanized iron, with longitudinal seams crimped and circular seams riveted and soldered.

For factories, some churches and some school buildings, a single-pipe system will meet all ordinary requirements, but to maintain the highest possible sanitary standard of air purity in schoolrooms a two-pipe system is indispensable; the mixing dampers for each room should be controllable automatically or arbitrarily from each such room; when arranged for automatic control a high order of intelligence, or carefulness, on the part of an engineer or janitor, is not a prerequisite for securing desired results; rooms can be individualized and equable temperature secured without lessening the volume of ventilation; it is the ideal arrangement.

A two-pipe system, as ordinarily applied, makes necessary that the fan shall force the cold air — blow it — across the radiating surfaces, the heater being between the fan and the rooms to be warmed and ventilated, with a by-pass valve so arranged that air can be forced through the heater — in contact with the radiating surfaces — or over or under, without contact, and into cold-air ducts; branch pipes from the main warm and cold air ducts open into the base of heat risers, which open to rooms. The general principle is correct, but the application of *fan to blow through the*

heater is poor engineering practice — it has resulted in numerous unsatisfactory plants and many failures.

The "unknown quantity" can be eliminated and a more positive application be secured by using two fans, one to deliver the warmed and the other to deliver the cold air to the heat-riser flues.

Right angles, in air pipes, should be avoided.

Memorandum, Subject ....

AUTOMATIC TEMPERATURE REGULATORS.

There are several patented mechanisms for automatically controlling temperatures, individualizing rooms without lessening the volume of ventilation. The electric system is quick-acting—blows all hot or all cold; the valves open and close alternately, with varying temperatures, will not balance between open and shut, *thus making "tempering coils"* NECESSARY.

The hydro-pneumatic regulator produces like results as the electric service, but is slower to start either way. Until it shall be tested on large work in order to demonstrate that its delicate mechanisms will maintain their adjustments it must be considered as an experiment.

The Powers system, operated by vapor pressure, is, in my opinion, the most simple in its mechanisms, most durable, least liable to get out of working order, and most efficient; the valves will poise between extremes, as warm or cold air supply shall be required to maintain an equilibrium of temperature in connecting rooms.

Fig. 16 shows a warm and cold air pipe with mixing dampers or valves so connected that as one opens the other closes, a change of three or four degrees in the temperature of the room where the thermostat is located being required to fully operate them. If set at seventy degrees the hot-air damper commences to close at, say, sixty-eight degrees, the cold-air damper opening at the same time. Should the temperature rise to seventy-two degrees, the hot air will all be shut off and the full volume of cold air will be delivered into the room.

It is apparent that under ordinary conditions the temperature would cease to rise before reaching this point, as the dampers

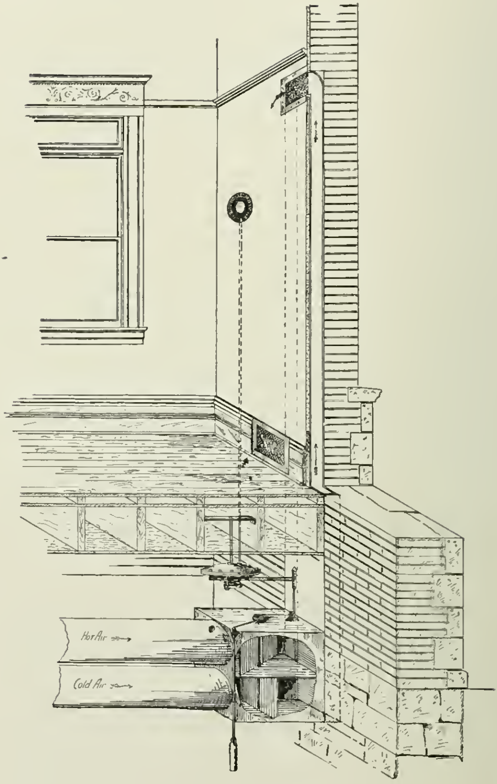


FIG. 16.
"The Powers" Automatic Temperature Regulatoı

gradually moving change the relative conditious of the hot and cold air supply and a permanent temperature of about seventy degrees will result, the dampers both being partly open, and this without the necessity of any tempering coil, the placing of which entails extra expense.

When used with two fans or a triple fan, the volume of ventilation will increase when a room becomes slightly overheated.

BOILERS.

In churches, schools and other public buildings, *safety for occupants* should have first and constant consideration in the development of plan and application of the mechanisms required for heating and ventilating plants.

Water-tube boilers provide high factors of safety and economy, and are recommended. Their use makes necessary greater height between floor and ceiling of boiler rooms, and is a condition for which architects should provide in plans.

Horizontal tubular boilers, made of open-hearth, homogeneous steel plate of 60,000 pounds tensile strength and standard thicknesses, tested at 150 pounds hydrostatic pressure, will have a safety factor exceeding four hundred per cent; they should be proportioned for maximum requirements with not to exceed twenty-five pounds steam pressure, and have a lever safety valve set to blow off at fifty pounds pressure. *Pop valves may cause a panic.*

SPACE REQUIRED.

Horse-Power.	Size.	Floor Space.	Height of Brick and Front.	Top of Dome.
20	36" by 10'	14' 6" by 68"	92"	106"
25	42" by 10'	14' 8" by 74"	98"	111"
30	44" by 10'	15' by 76"	100"	117"
35	44" by 12'	17' by 76"	100"	117"
40	44" by 14'	19' by 76"	100"	117"
45	48" by 14'	19' 2" by 88"	105"	124"
50	54" by 12'	17' 6" by 94'	112"	138"
60	54" by 15'	20' 8" by 94"	112'	138"
70	60" by 14'	19' 10" by 108"	118"	146"
80	60" by 16'	22' by 108"	118"	146"
90	66" by 15'	21' 6" by 114"	124"	156"
100	66" by 16'	22' 2" by 114"	124"	156"

For double settings double the width will be safe for space required.

Half-iron fronts should not be tolerated for a first-class plant.

HEATING BY STEAM.

Perfection in the use of steam for heating purposes requires that there be a thorough distribution of steam through the entire heating apparatus without air clogging and water hammering. To secure the best results steam at low pressure should be used. The entire heating apparatus should be so arranged as to remove air from the heating system and prevent the accumulation of water of condensation at any point.

Steam at atmospheric pressure contains 990 heat units or degrees of latent heat and 212 degrees of sensible heat. This steam, circulated through the heating apparatus under the proper conditions, will not condense until it reaches the delivery side of the vacuum apparatus, which secures such circulation.

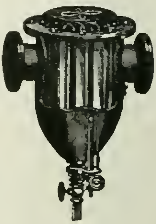


FIG. 17.
Oil Separator.

As the steam flows through the heating apparatus the air in the system will naturally flow through with the steam, and as it nears the greater vacuum it remains in a vaporous condition.

The vacuum system requires no air valves and consequently there can be no emission of air, the whole apparatus being sealed from the source of supply back to the boiler-feeding apparatus.

Exhaust steam from power plants can be utilized in the building containing the heating plant and also in buildings contiguous to power plant, with perfect results in heating, without back pressure on the engines connected; the water of condensation being returned to the boiler at a very high temperature.

Many heating plants are in operation where exhaust steam is carried thousands of feet away from the plant and returned to the power plant for boiler feeding without back pressure on engines. All back pressure on engines or pumps means loss of power and, consequently, loss of fuel.

Exhaust steam should be taken direct to the heating system without passing through an apparatus that would rob the steam of its latent heat, reducing the heating power. Any steam that may be needed to increase the supply over and above what is furnished by the engine power plant should be fed through a pressure-regulating valve, which valve would be under control of the engineer of plant and be used only when needed.

The feed-water apparatus should be of such a character as to utilize *all drip, from every source*, in winter, and exhaust steam in summer, when steam is not needed for heating purposes, without back pressure on engines.

An oil extractor should be placed on the exhaust steam feed to buildings to prevent the cylinder lubricant from entering the heating apparatus.

THE WILLIAMES VACUUM SYSTEM OF STEAM HEATING

Is comparatively new to the majority of steam users, and although it has been in use some ten years in the eastern states, it is still antagonized by a great many steam engineers, because they do not understand the principles involved and the results secured. This vacuum system enables steam users to make use of all steam for heating purposes, thereby totally preventing any waste through the roof and through drips to sewers, up to the amount of steam required for heating.

The vacuum system properly arranged will secure a perfect circulation of steam throughout all parts of a heating apparatus without any air clogging or water hammering, totally preventing the accumulation of both air and water.

It is a well-known fact, in large cities, steam that is allowed to escape to sewers is entirely from those heating systems carrying pressure above the atmospheric line, which causes a very great waste and is very destructive on sewers, and maintains a dangerous condition liable to cause explosions; the Williames Vacuum System of Steam Heating totally prevents such conditions.

The attention required from the parties operating a plant to secure a free circulation of steam throughout the entire heating system is reduced to the minimum. All the water of condensation is returned to the Webster "Vacuum" Feed-Water Heater and Purifier, which is a receptacle for drip in winter and a feed-water heater and purifier in summer, giving perfect results under both conditions.

The Williames Vacuum System of Steam Heating totally prevents back pressure on engines and pumps connected to the heating system; if there is a surplus of exhaust steam available for heating, the back-pressure valve is never closed; circulation is secured by means of the vacuum apparatus, drawing the air out of the heating system, causing a flow of steam through every part where heat is required.

Where there is not sufficient exhaust steam to do the work of

heating, live steam can be used in connection with the exhaust steam, and be fed through a pressure-regulating valve under perfect control. At times when live steam is used in connection with exhaust steam, the back-pressure valve will be closed, in order to prevent the atmosphere from flowing into the heating system, causing waste.

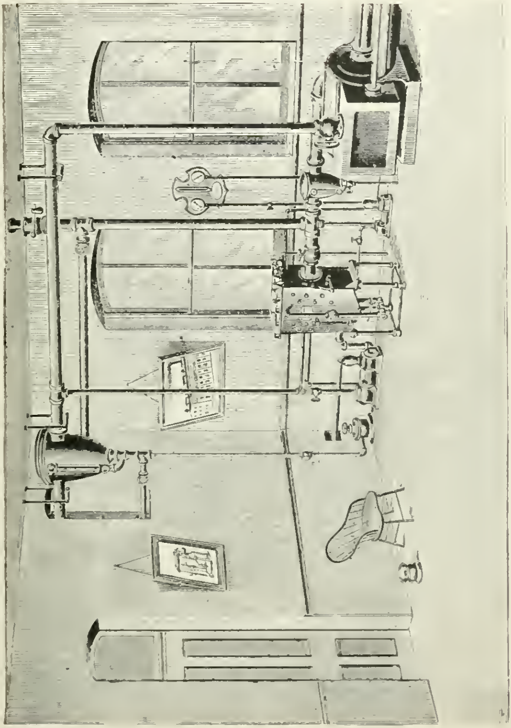
LOW-PRESSURE GRAVITY SYSTEM OF STEAM HEATING.

The essentials for securing the best results possible in a low-pressure gravity system of steam heating, using exhaust steam or live steam at the same pressure, say within five pounds above the atmospheric line, are that all piping be so arranged as to prevent any possibility of water collecting in the different mains supplying the system, and of such area as will not crowd the steam and water of condensation as they flow together in different currents.

There should be no feed-water heater of any type used on the steam-feed lines to heating system because they cause waste and increase the difficulties with air and water. A pressure feed-water heater which heats the water for boiler feeding by radiation is a disadvantage, because it increases the amount of friction, saturates the steam used for heating, and causes a waste through the drip of heater to sewer.

An open heater should not be used because it is a saturating device which increases the difficulty with water and air and robs the steam of latent heat which is needed for heating purposes. The steam feed lines should be arranged to take the steam from engines in its best condition direct to the heating system without any intervening device that would cause additional friction and the saturation of the steam.

Such a device should be constructed to serve as a receptacle for drip in winter and a feed-water heater during that part of the year when heating is not required, and be so connected as not to cause the steam used for heating purposes to pass through it. Being simply a receptacle for drip, the working conditions of such a device would be that the pressure on same be much less than required for circulating steam through the building. Such a device, properly constructed, being sealed from the atmosphere in order that a partial vacuum can be maintained, will assist in accelerating the flow of steam through the heating system during the heating season of the year.



Webster's "Vacuum" Feed-Water Heater and Purifier, Williames' Vacuum System of Steam Heating,
Webster's Separator for Live Steam, Webster's Oil Separator for Exhaust Steam,

As connected in a modern engine room.

DISTRIBUTED RADIATION.

In the primary stages of the development of mechanical heating and ventilation combination systems were installed, i. e., direct radiation was used in some rooms and indirect radiators were connected with other rooms to provide ventilation in the same building, both being connected with the same source of heat supply and dependent on gravity and difference in temperature for the return of water—the result of condensation—to the boiler. To the indirects air was delivered through galvanized iron ducts connecting from a fan blower.

The general principle was correct. That the system failed to lead in after-developments was due to several causes. First, fan capacities, as rated in catalogues, deceived. No reliable data as a basis for the proportioning of air supply and radiating surface were obtainable. The radiators used were not constructed properly and the applications were made without regard to natural laws which control the movements of air. Volume, velocity, contact, the effect of right angles on air movements, and short circuits, were not known factors in plan and proportions. In the meantime fan manufacturers were each developing hot-blast apparatus which (with but one exception) differs only in certain details of construction.

It would be unwise to assume that even approximate perfection has been attained for mechanical systems. The general principle proves to be correct, and the necessity for individualizing rooms—under certain conditions—has been determined, but it may be possible to make better applications of the main general principle.

To individualize rooms it means that two fans must be installed, one to blow hot air and the other cold air through separate ducts to the base of heat risers, or one fan be installed to blow air through a heater into one set of ducts or "pass" by the heater into another set of ducts, one hot-air and one cold-air duct connecting with a heat riser. The two-fan double-pipe system is the safer, and will be most efficient.

Distributed radiation properly proportioned and scientifically applied makes not only possible but practicable a single-pipe system with a fan to handle cold air and force it in contact with radiating surfaces—or "by-pass" without heating in part or entire—and thence to rooms to be warmed and ventilated. Under such conditions a fan will be more efficient than if a mass of radiating surface be close to the point of discharge of the fan wheel.

A distributed radiation mechanical system possesses one important essential, namely, it can be used on "natural circulation" to maintain temperatures at times when the fan shall not be in operation and thereby save the cost of installing direct radiation for that purpose; with mechanical heating and ventilation, as applied, heating is dependent entirely upon the fan being operated; when it is not operated rooms cool quickly, hence, in school buildings the fan must be operated continually or heating and ventilation ceases; or to make heating possible radiators must be installed in rooms. These will maintain temperature but will not provide ventilation.

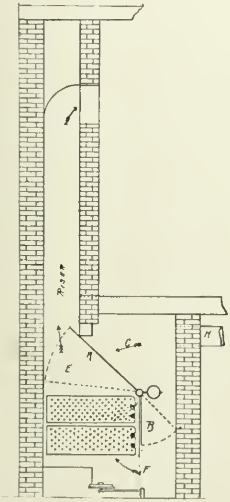


FIG. 18.
Application of distributed radiation with mechanical ventilation.

In a plant as ordinarily installed with a fan *blowing air* in contact with radiating surfaces, massed within three to six feet of the fan wheel periphery, the air contact is at velocities ranging from 43 feet to 75 feet, and sometimes 86 feet per second, and the volume is not evenly distributed; the entire radiating surface is not alike efficient.

In a mechanical system with distributed radiating surfaces air velocities can be decreased to about 22 feet per second and the volumes be distributed evenly in contact with the radiating surfaces. The general adaptability of such an application in connection with school buildings is commended.

Fig. 18 shows an indirect radiator constructed for distributed radiation and mechanical ventilation, and usable with arbitrary or automatic heat control.

When such an installation is made, straight-way valves should be used, and the return pipes for water, the result of condensation, be ample in area and connect with a pump and receiver with automatic governor to be used when the fan shall be operated. A "by-

pass" around the pump and receiver should be installed so that when "natural circulation" is used (with low steam pressure) water may be returned by gravity.

WASTEFULNESS.

While looking from a window on the fifteenth floor of the Monadnock building and observing smoking chimneys and escaping steam, the above headline was suggested because in it was expressed the economic condition presented to sight. Crossing the Chicago river and seeing hot water and steam from the sewer pipes of individual buildings emptying into the river, and when walking along the streets and seeing steam escaping from manholes fixed in mind "wastefulness," and suggested the thought, "What does the needless waste from those sources cost Chicago daily — \$50,000 — \$100,000?" Sewers hide the bad work of installing and operative engineers as effectually as the grave is said to hide the bad work of doctors. Too frequently money value, equal to dividends on the cost of heating and power plants, is buried in sewers.

An experienced engineer who has investigated the municipal heating and power plants stated recently, "With proper appliances a saving to the city equal to at least \$30,000 yearly can be made, and if a proposition could be considered and a contract be executed free from political pull and the results be determined honestly, I would be glad to submit a proposition and undertake the work on the basis of an absolute guarantee as to the money value to be saved by each individual plant."

As a rule, the owners of private plants do not see the waste, are not familiar with the details of construction and operation, and in many instances are not capable of analyzing conditions. For public heating and power plants the taxpayers foot the bills, do not investigate the economic features, and operatives manipulate apparatus in such manner as requires the least possible personal effort; economy is ignored.

With proper appliances and care it is possible to save from ten to twenty-five per cent as compared with operating costs as ordinarily made by average steam plants.

It is true that city ordinances prohibit the discharge of steam into sewers, because it disintegrates them, but the law is ignored.

Members of boards of public works and sanitary experts who have not had the experience which will enable them to know at sight the steam leakage from buildings, should be compelled to

WASTEFULNESS — Observable from the fifteenth floor of the Monadnock Building, looking east.

WASTEFULNESS — Observable from the fifteenth floor of the Monadnock Building, looking west.

pass through sewers and locate such discharges as are made in violation of law.

From the standpoint of the owner and user, every gallon of hot water discharged into sewers represents money value equal to that required to heat a like quantity from the normal temperature of water up to 212° Fahr.

AIR VALVES.

When either direct or indirect radiators are installed, air valves attached thereto become a necessity and nothing short of those which are automatic in their operation should be accepted. With regard to most of the so-called automatic air valves there has been much of theory and claim, and while some are good in part most have lacked in some essential points which hinder their perfect working qualities and disappoint users.

Fig. 19 illustrates an automatic air valve with heat controller attachment. The valve has a double opening, one connecting

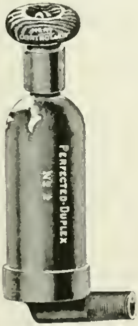


FIG. 19.
Air valve with heat controller.

FIG. 20.
Automatic Air Valve with air tube for exterior displacement of foul air.

from the radiator to the base of the valve, and the other opening to the space between the valve and the inclosing chamber walls, the latter opening terminating at a point above the top of the float. Air from the radiator passes through the tube to the top of the valve, forcing the water out of the valve through the larger

and lower opening back into the radiator, when the float will drop and open the valve at the top for permitting the escape of air from the radiator. This action will continue as long as water enters and until every particle of air is taken from the radiator; then as steam enters, the stick of vulcanite will expand and close the valve seat by raising the brass float. The small tube extending up above the float, through which air passes, is an important factor, as it equalizes the pressure in the valve at all times and keeps it free from water.

Another important matter is the fact that the inclosing shell is made in one piece and cannot burst or go apart. There are no soldered joints in the construction of this valve.

Illustrative of the danger in using air valves made in parts with soldered joints: the latter part of the winter of 1893-94, there was an explosion in one of the public school buildings in Chicago which caused a panic, resulting in the loss of several lives. The cause of the explosion was the separation of the joints of an automatic air valve. I use the illustration as a caution to architects and owners of buildings, especially those who control conditions where child life is at risk.

The heat controller makes a combination by which the valve may be adjusted for automatic working; or, by partially closing down the heat controller a portion of a radiator will remain usable, i. e., transmit heat as may be required to meet the conditions in a room. For instance, in mild weather the entire radiating surface will be in excess of the requirements, hence, to maintain an even temperature is impossible for the reason that the steam must be on or off, but with the heat controller the feed valve or feed and drip valve (if a two-pipe system) will require no attention. The entire control or divisibility of the radiating surface into working parts will be made by the heat controller which will make a part of the radiator inoperative. Fig. 20 shows a perfected duplex automatic steam air valve, separate from the heat controller; the construction and internal mechanism of this valve is the same as that shown by Fig. 19. The valuable feature of this valve (in addition to its automatic operation) *is the tube connection* so as to conduct the foul air displaced from radiators into pipes connecting with the basement or exterior of the building, so that rooms shall remain free from the odors which are inseparable from steam-heated apartments when foul air from radiators shall be expelled therefrom into such rooms.

It is a well-known fact that steam-heated apartments have a

close stuffy smell, caused more frequently by air discharged from valves than from causes exterior to the radiators.

Where a vacuum system of heating shall be installed connections from the air tubes on radiators should connect back thereto which will provide for quick circulation and freedom from the odor nuisance mentioned heretofore.

DEFLECTING SHIELDS.

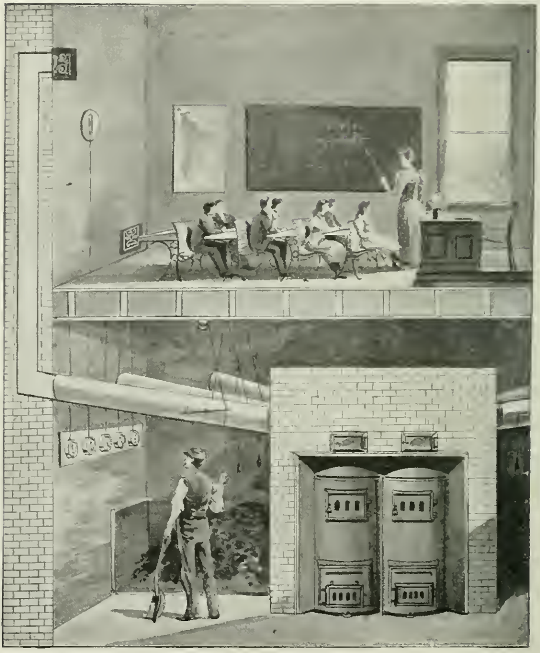
One of the principal objections to the use of direct radiators in heating by steam or hot water is the discoloration of the walls and ceilings in their immediate vicinity. When a radiator is in operation there are continuous vertical currents of air passing over its entire surface. These air currents rise from the floor, and being warmed in their vertical passage over the radiator ascend to the ceiling, carrying with them quantities of fine dust and other impurities.

These ascending currents of air cling closely to the radiator until they reach the top thereof, when they immediately spread out fan-like in all directions above the radiator and deposit upon the walls and ceiling dust and other impurities, entirely ruining wall paper and other decorated surfaces with which they come in contact.

FIG. 21.
Deflecting Shield.

The old style sheet-iron hood or screen which stands on the floor and entirely covers up the radiator, except in front, is altogether too unsightly to use where appearance is a consideration; moreover, it has the objectionable features of considerably reducing the efficiency of the radiator by preventing the free circulation of air and the emission of radiant heat, also of forming a receptacle for dirt almost impossible to clean out. Deflecting shields effectually prevent the discoloration of walls, ceilings, etc., while at the same time the entire surface of the radiator is freely exposed to the surrounding atmosphere, not only maintaining its full efficiency but materially increasing it by deflecting the currents of warmed air horizontally into the lower part of the room instead of allowing them to ascend directly to the ceiling.

As no portion of the radiating surface is inclosed by the deflecting shields the maximum emission of radiant heat is always obtained from the radiator.



Powers' Telethermometer as applied in a schoolroom.

MECHANICAL HEATING AND VENTILATING APPARATUS.

RULES FOR PROPORTIONING.

A.— Heater : For Factories.

$\frac{\text{Cubic feet space to be heated}}{100}$ = feet of 1-inch pipe for heater.

Fan : For Factories.

$\frac{\text{Cubic feet space} \times 3}{60}$ = cubic feet of air required per minute ; this, if based on ½-ounce pressure, will make possible an increase of about twenty per cent in heat-producing power by increasing the revolutions of the fan wheel to that required for ¾-ounce pressure. The higher speed is not advisable for regular use but may be used, temporarily, to meet extraordinary requirements caused by extreme low temperature — winter conditions.

B.— For School, Church, Hospital and other Public Buildings.

1. If ventilation shall base on times change per hour,

$\frac{\text{Cubic feet of space to be heated} \times \text{times change per hour}}{300}$ = feet of pipe for heater.

2. $\frac{\text{Cubic feet of space to be heated} \times \text{times air change per hour}}{60}$ = cubic feet of air required per minute.

C.— If ventilation shall base on a required quantity of air per person per hour :

Number of persons × cu. ft. of air per hour	=	....
Cubical contents of corridors, etc. × 3	=	....
" " " toilet rooms × 6	=	....
= total cubic feet of air per hour required,		....

2. $\frac{\text{Cubic feet of air per hour required}}{60}$ = cubic feet of air per minute required.

3. $\frac{\text{Cubic feet of air per hour required}}{300}$ = feet of 1-inch pipe in heater required for heating.

FOR BOILER CAPACITY REQUIRED.

A.—10 H.P. boiler for each 1,000 feet of 1-inch pipe in heater, or,

B.— $\frac{\text{Square feet of radiating surface}}{33}$ = H. P. of boiler required

For churches, schools and other public buildings boiler pressur should base on about twenty pounds.

ENGINE POWER.

The ratings of engines all being based on high steam pressures, and as steam pressures on boilers used in school and church buildings should be limited to about twenty pounds, architects and others need a simple and convenient formula for determining powers at any desired pressure.

RULE. — M. E. P. (in pounds per square inch) × double the piston speed (in feet) × the square of piston diameter (in inches) and point off five figures from the right.

Example.— Engine 10 inches by 12 inches cylinder, at 200 R. P. M., at 20 pounds M. E. P.

20 × 800 × 100 = 1600000 or 16 H. P. The gross H. P. would be,

$$\frac{20 \times 78.54 \times 400}{33,000} = 19.04 - 15 \text{ per cent for friction} = 16.1 \text{ H. P. net.}$$

(Grimshaw.)

Or, 2. Pressure × length of cylinder (in feet) × area of piston × number of strokes (per minute) ÷ 33,000 = — 15 per cent for friction = H. P.

The size or capacity of a steam engine is based on: The steam pressure carried in the boiler, the point of stroke at which the steam is "cut off" from cylinder, the size of cylinder, and speed of engine.

The *pressure* is the mean effective pressure on the piston, and is fixed by the pressure in the boiler (i. e., pressure in pounds by steam gauge) and the point of cut-off of steam admission.

For ordinary slide-valve engines, such as are used for heating plants, the cut-off takes place at one-fourth to one-half the stroke.

Length of Stroke — is taken in feet and may safely be assumed as that of catalogue length of cylinder.

$$\frac{\text{Length of cylinder in inches} \times 2 \times \text{R. P. M.}}{12} = \text{feet travel per min.}$$

Area of piston, or area of cylinder, is equal to the square of diameter of cylinder (in inches) × 0.7854.

Square of piston diameter — is diameter × diameter.

Number of strokes — is equal to twice the number of R. P. M.

The calculated H. P. must be discounted ten to twenty per cent for engine friction in order to arrivé at available H. P.

TO CHANGE SPEED OF ENGINES.

$$\frac{\text{Diameter of pulley on main shaft} \times \text{R. P. M. desired}}{190} = \text{governor pulley, diameter in inches required.}$$

SIZE OF STEAM PIPE REQUIRED FOR SLIDE-VALVE ENGINE.

$$\frac{\text{Diam. of cyl. in ins.}}{90} \times \text{sq. root of piston speed in ft. per min.} = \text{diameter of steam pipe in inches.}$$

If the pipe is longer than 240 times its inside diameter, or has many bends in it, due allowance must be made for friction of steam in the pipe.

Engine foundation — should be built up of masonry in a substantial manner and the top finished by a cap stone faced true and set level. Engine bed-plate should be set in sulphur (melted and poured in) or by a rust joint. Allow from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch for joint between the cap stone and engine bed.

Foundation bolts should be built into the masonry and the cap stone be carefully drilled and set in place over the bolts, leaving the bolts projecting sufficiently to reach through bed-plate and nut on top. The foundation should be entirely free from all walls or foundation footings and be entirely independent from the floor. If the building is of modern steel construction, extreme care should be taken to preclude any possibility of transmitting any vibrations. Vibrations may be felt in a building when there is no apparent vibration in the engine.

BELTS.

Width of belt required to transmit given power. An allowance of 60 square feet of belt contact per minute per H. P. is good practice, and a maximum of 80 square feet is sometimes used for extreme conditions. The above is for belt embracing one-half of circumference of pulley or 180°, the pulleys being the same diameter. When the pulleys are unequal in size the smaller pulley determines the power transmitted.

Arc of pulley,	180°	135°	112°	90°	67°	45°
Power, . .	1	0.90	0.83	0.74	0.62	0.46

RULES.—1. $\frac{\text{Belt speed in ft. per min.} \times \text{width of belt in ft.}}{60} = \text{H.P.}$

2. $\frac{60 \times \text{H. P.}}{\text{Belt speed in ft. per min.}} = \text{width of belt in inches.}$

The power-transmitting capacity of a single leather belt is to the capacity of a double belt as 7 : 10, i. e., if a double belt of a given width and speed will transmit 10 H. P., a single belt of the same width at same speed will transmit 7 H. P.

A working tension of 56 pounds per inch width for single, or 80 pounds per inch width for a double belt is safe practice to figure on for power. A contact of 60 square feet per H. P. per minute usually keeps well inside of these figures.

Example.—Assume a 6-inch belt running at 4,000 lineal feet travel per minute. To find H. P.: $\frac{4{,}000 \times \frac{1}{2}}{60} = 33\frac{1}{3}$ H. P.

$$\frac{33{,}000 \times \text{H. P.}}{\text{Belt speed in feet per minute}} = \text{working tension on belt.}$$

Example.— $\frac{33{,}000 \times 33\frac{1}{3}}{4{,}000} = 275$ pounds on belt.

$\frac{275}{6''} = 46$ (nearly) lbs. per inch, so a single belt will safely carry the load.

STEAM TRAPS.

RULE.— $\frac{\text{Manufacturers' list sq. ft. radiating surface}}{4}$ = sq. ft. of radiating surface $\times$ 2.9 = lineal feet of 1-inch pipe in hot-blast heater it will drain.

Or, $\frac{\text{manufacturers' list, lineal feet of 1-inch pipe}}{4}$ = feet of 1-inch pipe in heater the trap will drain.

The rule is applicable to all steam traps.

The following detail will be convenient :

STEAM TRAPS (FIDELITY).

No.	Lineal feet of 1″ pipe, Manufacturers' Rating.	Lineal feet of 1″ pipe, Hot-blast Rating.	Inlet.	Outlet.	Floor to Inlet.	Floor to Outlet.	Pounds Weight.
00	1,000′	250′	1 ″	$\frac{3}{4}$″	10 ″	3 ″	80
0	2,000′	500′	1 ″	$\frac{3}{4}$″	10 ″	3 ″	80
1	4,000′	1,000′	1 ″	$\frac{3}{4}$″	10 ″	3 ″	80
2	7,000′	1,750′	$1\frac{1}{4}$″	1 ″	$11\frac{1}{2}$″	$3\frac{1}{4}$″	115
3	10,000′	2,500′	$1\frac{1}{2}$″	$1\frac{1}{4}$″	12 ″	$3\frac{3}{4}$″	130
4	15,000′	4,000′	2 ″	$1\frac{1}{2}$″	14 ″	4 ″	150

Capacity ratings based on 80 pounds steam pressure.

PUMPS AND RECEIVERS.

RULE.—Manufacturers' list sq. ft. radiating surface / 4 = sq. ft. radiating surface × 2.9 = lineal feet of 1-inch pipe in hot-blast heater it will drain with reasonable speed or stroke of pump cylinders.

Or, lineal feet of 1-inch pipe (manufacturers' rating) / 4 = 1-inch steam pipe in heater the pump will drain.

An examination of capacity ratings for pump and receivers as listed by manufacturers shows differences, for like sizes, averaging about twenty-five per cent. Because of the differences in *claims* that of lowest rating is used in the following table:

PUMP AND RECEIVERS WITH AUTOMATIC GOVERNORS.

Diameter of Steam Cyls. in inches.	Diameter of Plungers in inches.	Length of Stroke in inches	Size of Steam Supply Pipe	Size of Steam Exhaust Pipe.	Size of Receiver Inlet Pipe.	Size of Pump Discharge Pipe.	Gallons Capacity per minute.	Rating for 1-in. Steam Pipe for ordinary installations.	Rating for 1-in. Pipe. Hot blast.	Floor Space. Length	Floor Space. Width.	Floor Space. Height.
3 "	2 "	3"	½"	½"	2½"	¾"	9	1,724	[illegible]	38	24	[illegible]
4½"	2¾"	4"	½"	¾"	2½"	1½"	15	3,45[illegible]	[illegible]	42	29	23
5¼"	3½"	5"	[illegible]	1¼"	2½"	1½"	[illegible]	[illegible]	[illegible]	45	31	25
6 "	4 "	6"	1 "	1½"	2½"	2 "	50	13,[illegible]	3,4[illegible]'	[illegible]	33	28

With ordinary winter conditions the ratings for hot blast could be raised thirty per cent. Maximum winter requirements must be provided for, and ratings are based on that duty.

BOILER SAFETY FACTORS.

UNITED STATES GOVERNMENT RULE.

$$\frac{\frac{1}{6}\text{ tensile strength} \times \text{thickness of shell}}{\text{half the diameter of shell}} = \text{safe working pressure.}$$

Example.—Boiler 54 inches by 12 feet, shell $\frac{3}{8}$ inch, 60,000 pounds tensile strength; $\frac{1}{6}$ of $60{,}000 = 10{,}000 \times \frac{3}{8} = \frac{3{,}750}{27} = 138$ pounds for single-riveted boilers.

For double-riveted boilers add twenty per cent.

AIR PRESSURE DUE TO VELOCITY.

11	feet	per	second	=	$\frac{1}{32}$ oz.
15.5	"	"	"	=	$\frac{1}{16}$ oz.
22.	"	"	"	=	$\frac{1}{8}$ oz.
43.	"	"	"	=	$\frac{1}{4}$ oz.
60.	"	"	"	=	$\frac{1}{2}$ oz.
74.7	"	"	"	=	$\frac{3}{4}$ oz.
86.2	"	"	"	=	1 oz.

At 60° Fahr. 1 oz. pressure per sq. in. = 1.729 "water column."
At 60° Fahr. 1 oz. " " " = .1273 "mercury."

PIPE RADIATION.

2.903	feet of	1-inch	pipe	=	1	square	foot	of	radiating	surface.
2.301	"	$1\frac{1}{4}$	"	=	1	"	"	"	"	"
2.010	"	$1\frac{1}{2}$	"	=	1	"	"	"	"	"

COMBUSTION.

COAL.— Bituminous. Twelve pounds per hour for each square foot of grate surface is a fair average for ordinary firing, i. e., working a boiler on high duty. For mechanical heating and ventilation the average horizontal tubular boiler, kept in proper condition, will require four to eight pounds of bituminous coal per hour per square foot of grate surface.

AIR REQUIRED FOR COMBUSTION.

Remember, approximately 125 cubic feet of air per minute per square foot of grate surface is required. A tightly closed boiler room means hard firing, poor combustion, and a smoky chimney.

TO FIND CAPACITY OF A CYLINDRICAL VESSEL IN GALLONS.

RULE.—Multiply area in square inches by the height in inches and divide the product by 231.

For rectangular vessel — multiply height, width and length in inches and divide the product by 231.

PAINT FOR STEAM PIPES.

Asphaltum dissolved in turpentine is the best varnish for steam pipes, smoke stacks, etc.

Or,

"Graphite Paint" can be obtained in colors and black. It makes a durable and neat finish, gives off no odor from hot pipes, and does not fade.

FANS.

For Planing Mill use.

For 2-ounce pressure, factor	7338.24
" 3 " " "	9006.42
" 4 " " "	10421.58
" 5 " " "	11676.00
" 6 " " "	12817.08

Rule.—To determine the revolutions per minute for the pressure required: Find the circumference of the wheel in feet and divide the factor opposite the vacuum or pressure; the quotient will equal the R. P. M. required.

Example.—Wheel 66 inches diameter for 4-ounce pressure;

$$\frac{3.1416 \times 66 \text{ (inches diameter)}}{12} = 17.27 \text{ feet circumference.}$$

$$\frac{\text{(Factor) } 10421.58}{17.27} = 604 \text{ R. P. M. for 4-ounce pressure.}$$

10,000 to 12,000 lineal feet travel of wheel is required.

Memorandum, Subject

SCHEFFLER'S TABLE OF MEAN EFFECTIVE AND TERMINAL PRESSURES AT DIFFERENT POINTS OF CUT-OFF AND INITIAL PRESSURES.*

Initial Pressure.	POINT OF STROKE AT WHICH STEAM IS CUT OFF.									
	$\frac{1}{8}$		$\frac{1}{5}$		$\frac{1}{4}$		$\frac{3}{8}$		$\frac{1}{2}$	
	M. E. P.	T. P.	M. E. P.	T. P.	M. E. P.	T. P.	M. E. P.	T. P.	M. E. P.	T. P.
100	26.2	19.1	41.8	27.1	49.6	32.8	65.8	46.5	76.9	60.2
95	23.6	18.3	39.1	25.9	46.5	31.4	62.1	44.5	72.7	57.6
90	21.1	17.5	36.5	24.7	43.5	30.	58.5	42.5	68.6	55.0
85	19.8	16.6	34.	23.5	40.6	28.5	54.6	40.4	64.5	52.3
80	18.6	15.8	31.6	22.4	37.8	27.1	50.7	38.4	60.4	49.7
75	16.7	14.9	28.8	21.2	34.9	25.6	47.	36.	56.8	47.1
70	14.7	14.1	26.1	20.	32.1	24.2	43.4	34.4	53.2	44.5
65	13.	13.3	23.7	18.8	29.2	22.8	39.8	32.3	49.0	41.8
60	11.3	12.5	21.4	17.7	26.4	21.4	36.2	30.3	44.9	39.2
55	9.5	11.6	18.7	16.5	23.5	19.9	33.2	28.3	40.9	36.6
50	7.8	10.8	16.1	15.3	20.7	18.5	30.2	26.3	36.9	34.0
45	6.	9.9	13.7	13.6	18.9	17.	26.5	23.9	31.7	31.0
40	4.6	9.1	11.1	12.3	15.9	15.4	22.8	21.9	27.5	28.4
35	2.7	8.1	8.5	11.	12.7	13.9	19.1	19.8	23.3	25.8
30	1.2	7.	5.9	9.9	9.7	12.3	15.9	17.7	19.0	23.2
25	.36	6.	3.3	8.6	6.8	11.2	12.2	15.6	14.8	20.6
20	......	4.	1.03	7.3	3.8	9.1	8.5	13.5	10.6	18.0
15	......	3.	......	6.	.8	7.5	5.2	11.4	6.3	15.4

The above table is only for engines with single valves, and allowance is therefore made for exhaust opening and compression which vary at each point of cut-off. The "terminal pressure" is measured from absolute vacuum and is the pressure at end of stroke if the steam had been expanded to that point.

*T. F. Scheffler, M.E., Erie, Pa.

BOILER PRESSURE EQUIVALENTS.

Boiler Pressure Reduced to Lbs. per Square Inch. By Gauge.	POUNDS STEAM PRESSURE CARRIED IN BOILER. PER SQUARE INCH (BY GAUGE).																							
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
5	1.23	1.40	1.69	1.92	2.15	2.37	2.59	2.81	3.02	3.24	3.46	3.68	3.90	4.11	4.32	4.53	4.74	4.95	5.16	5.37	5.58	5.79	5.99	6.19
10	1.00	1.19	1.37	1.55	1.74	1.92	2.10	2.27	2.45	2.62	2.80	2.97	3.15	3.32	3.50	3.67	3.84	4.01	4.18	4.35	4.52	4.69	4.85	5.01
15		1.00	1.15	1.31	1.47	1.62	1.77	1.91	2.06	2.21	2.36	2.50	2.65	2.80	2.95	3.09	3.23	3.37	3.51	3.65	3.80	3.94	4.08	4.22
20			1.00	1.13	1.27	1.40	1.53	1.66	1.79	1.92	2.04	2.17	2.30	2.42	2.55	2.67	2.80	2.93	3.05	3.17	3.29	3.41	3.53	3.66
25				1.00	1.12	1.23	1.35	1.46	1.57	1.69	1.80	1.91	2.02	2.13	2.24	2.35	2.47	2.58	2.69	2.79	2.90	3.01	3.12	3.23
30					1.00	1.10	1.21	1.31	1.41	1.51	1.61	1.71	1.81	1.91	2.01	2.11	2.21	2.31	2.41	2.50	2.60	2.70	2.79	2.89
35						1.00	1.09	1.19	1.28	1.38	1.47	1.56	1.65	1.74	1.83	1.92	2.00	2.09	2.18	2.27	2.36	2.45	2.53	2.62
40							1.00	1.08	1.17	1.25	1.34	1.42	1.50	1.58	1.67	1.75	1.83	1.91	1.99	2.07	2.15	2.23	2.31	2.39
45								1.00	1.08	1.15	1.23	1.31	1.38	1.46	1.54	1.61	1.69	1.76	1.84	1.91	1.99	2.06	2.13	2.20
50									1.00	1.07	1.14	1.21	1.28	1.35	1.42	1.49	1.56	1.63	1.70	1.77	1.84	1.91	1.98	2.05
55										1.00	1.07	1.13	1.20	1.26	1.33	1.39	1.46	1.52	1.59	1.65	1.72	1.78	1.84	1.90
60											1.00	1.06	1.12	1.18	1.24	1.30	1.37	1.43	1.49	1.55	1.61	1.67	1.73	1.79
65												1.00	1.06	1.12	1.18	1.23	1.29	1.35	1.41	1.47	1.52	1.57	1.63	1.69
70													1.00	1.06	1.11	1.16	1.22	1.27	1.33	1.38	1.43	1.49	1.54	1.59
75														1.00	1.05	1.10	1.15	1.21	1.26	1.31	1.36	1.41	1.46	1.51

RULE.—Tabular number corresponding to the given reduction of pressure cubic feet of steam at lower pressure equivalent to 1 cubic foot of steam at boiler pressure. This also gives comparative capacities.

Example.—1 cubic foot of steam at 100 pounds will equal 4.18 cubic feet at 10 pounds. And if 1 horse-power *rated capacity* of boiler will do the required work at 100 pounds, it will take 4.18 horse-power *rated capacity* of boiler to do the same work at 10 pounds.

SIZES OF CHIMNEYS WITH APPROPRIATE HORSE-POWER BOILERS.

The following table has been computed by means of the formulæ on page 68 of "Steam,"* and will be found useful for ready reference:

Diameter in Inches.	Height of Chimneys. 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft	Effective Area, square feet.	Actual Area, square feet.	Side of square of approximate area in Inches.
	Commercial Horse Power.													
18	23	25	27	...	...	...	...	...	...	...	...	0.97	1.77	16
21	35	38	41	...	...	...	...	...	...	...	...	1.47	2.41	19
24	49	54	58	62	...	...	...	...	...	...	...	2.08	3.14	22
27	65	72	78	83	...	...	...	...	...	...	...	2.78	3.98	24
30	84	92	100	107	113	...	...	...	...	...	...	3.58	4.91	27
33	...	115	125	133	141	...	...	...	...	...	...	4.47	5.94	30
36	...	141	152	163	173	182	...	...	...	...	...	5.47	7.07	32
39	...	...	183	196	208	219	...	...	...	...	...	6.57	8.30	35
42	...	...	216	231	245	258	271	...	...	...	...	7.76	9.62	38
48	...	...	...	311	330	348	365	389	...	...	...	10.44	12.57	43
54	...	...	...	363	427	449	472	503	551	...	...	13.51	15.90	48
60	...	...	...	505	539	565	593	632	692	748	...	16.98	19.64	54
66	...	...	...	...	658	694	728	776	849	918	981	20.83	23.76	59
72	...	...	...	...	792	835	876	934	1023	1105	1181	25.08	28.27	64
78	...	...	...	...	...	995	1038	1107	1212	1310	1400	29.73	33.18	70
84	...	...	...	...	...	1163	1214	1294	1418	1531	1637	34.76	38.48	75
90	...	...	...	...	...	1344	1415	1496	1639	1770	1893	40.19	44.18	80
96	...	...	...	...	...	1537	1616	1720	1876	2027	2167	46.01	50.27	86

* "Steam," used by permission of the Babcock & Wilcox Co.

TABLE

SHOWING VELOCITY AND PRESSURE OF WIND.

(HASWELL.)

Velocity. Per Hour.	Velocity. Per Minute.	Pressure on a Sq. Foot.	Character of Wind.	Velocity. Per Hour.	Velocity. Per Minute.	Pressure on a Sq. Foot.	Character of Wind.
Miles.	Feet.	Lbs.		Miles.	Feet.	Lbs	
1	88	.005	Barely Observable	25	2200	3.125	Very Brisk.
2	176	.02	Just Perceptible	30	2640	4.5	High Wind.
3	264	.045		35	3080	6.125	
4	352	.08	Light Breeze	40	3520	8	Very High Wind.
5	440	.125		45	3960	10.125	Gale.
6	528	.18	Gentle, Pleasant Wind.	50	4400	12.5	Storm.
8	704	.32		60	5280	18.	Great Storm.
10	880	.5	Fresh Breeze.	80	7040	32.	Hurricane.
15	1320	1.125	Brisk Blow	90	7920	40.5	Tornado.
20	1760	2	Stiff Breeze	[illegible]	8800	50	

TABLE OF PRESSURE, TEMPERATURE AND VOLUME OF STEAM.

Pressure above the Atmosphere.	Temperature.	Volume of 1 lb.	Pressure above the Atmosphere.	Temperature.	Volume of 1 lb.
Lbs.	°	Cubic Feet.	Lbs.	°	Cubic Feet.
1	213.1	25.85	39	284.7	7.88
2	216.3	24.32	40	285.9	7.74
3	219.6	22.96	41	287.1	7.61
4	222.4	21.78	42	288.2	7.48
5	225.3	20.7	43	289.3	7.36
6	228.	19.72	44	290.4	7.24
7	230.6	18.84	45	291.6	7.12
8	233.1	18.03	46	292.7	7.01
9	235.5	17.26	47	293.8	6.9
10	237.8	16.64	48	294.8	6.81
11	240.1	15.99	49	295.9	6.7
12	242.3	15.38	50	296.9	6.6
13	244.4	14.86	51	298.	6.49
14	246.4	14.37	52	299.	6.41
15	248.4	13.9	53	300.	6.32
16	250.4	13.46	54	300.9	6.23
17	252.2	13.05	55	301.9	6.15
18	254.1	12.67	56	302.9	6.07
19	255.9	12.31	57	303.9	5.99
20	257.6	11.97	58	304.8	5.91
21	259.3	11.65	59	305.7	5.83
22	260.9	11.34	60	306.6	5.76
23	262.6	11.04	61	307.5	5.68
24	264.2	10.76	62	308.4	5.61
25	265.8	10.51	63	309.3	5.54
26	267.3	10.27	64	310.2	5.48
27	268.7	10.03	65	311.1	5.41
28	270.2	9.81	66	312.	5.35
29	271.6	9.59	67	312.8	5.29
30	273.	9.39	68	313.6	5.23
31	274.4	9.18	69	314.5	5.17
32	275.8	9.	70	315.3	5.11
33	277.1	8.82	71	316.1	5.05
34	278.4	8.65	72	316.9	5.
35	279.7	8.48	73	317.8	4.94
36	281.	8.31	74	318.6	4.89
37	282.3	8.17	75	319.4	4.84
38	283.5	8.04	76	320.2	4.79

TABLE SHOWING SIDES OF SQUARES,

Equal in Area to a Circle of any Diameter, and Area of Each.

Diam. of Circle in inches.	Side of Square in inches	Area in Square inches.	Diam. of Circle in inches	Side of Square in inches	Area in Square inches.	Diam. of Circle in inches	Side of Square in inches.	Area in Square inches.
1	.8862	.7854	26	23.0419	53[illegible].93	51	4[illegible].976	2[illegible]
2	1.7724	3.1416	27	23.928[illegible]	[illegible]72.56	52	46.0835	2.23.
3	2.6587	7.0686	28	24.8144	[illegible]15.75	53	46.97	2206.
4	3.4549	12.5664	29	25.7006	660.[illegible]2	54	47.8562	2290.
5	4.4311	19.635	30	26.5868	706.86	55	48.74[illegible]	2376
6	5.3174	28.2744	31	27.473	754.77	56	49.6287	2463.
7	6.2036	38.[illegible]846	32	28.3593	8[illegible]4.25	57	5[illegible]49	2552.
8	7.0898	5[illegible]2[illegible]56	33	29.2455	855.30	58	51.[illegible]12	2642.
9	7.976	63.6174	34	30.1317	907.9	[illegible]	52.[illegible]74	2734
10	8.8623	78.54	35	31.0179	962.12	[illegible]	53.1736	2827.
11	9.7485	95.03	36	31.9042	1017.9	61	54.0598	2922.
12	10.6347	113.10	37	32.7904	[illegible]75.2	62	54.9[illegible]1	3019
13	11.5209	132.73	38	33.6766	1134.1	63	55.8323	3117.
14	12.4072	153.94	39	34.5628	1194.6	64	[illegible]7185	3217.
15	13.2934	176.72	40	35.4491	1256.6	65	[illegible]7.6[illegible]47	3318.
16	14.1796	201.06	41	36.3353	1320.3	66	58.491	3421.
17	15.0659	22[illegible]98	42	37.2215	1385.4	67	[illegible]9.3772	3526.
18	15.952	254.47	43	38.1078	1452.2	68	6[illegible].2634	36[illegible]2
19	16.8383	283.53	44	38.944	152[illegible].5	69	61.[illegible]497	3739
20	17.7245	314.16	45	39.8[illegible]	15[illegible].4	70	62.[illegible]	3848.
21	18.6108	346.36	46	40.7664	1661.[illegible]	71	62.[illegible]221	3959.
22	19.497	380.13	47	41.6327	1734.9	72	63.8[illegible]	4072.
23	20.3832	415.47	48	42.5839	1809.5	73	64.6946	4185.
24	21.2694	452.39	49	43.4251	1[illegible]5.7	74	65.5808	4301.
25	22.1557	490.88	50	44.3113	1963.5	75	66.467	4418.

TABLE OF THE WEIGHTS OF GALVANIZED IRON PIPE, IN POUNDS, PER RUNNING FOOT.

Diameter of Pipe.	Gauge of Iron.				
	No. 24.	No. 22.	No. 20.	No. 18.	No. 16.
4	1½	1⅝	2	2¾	3¼
5	1¾	2	2½	3⅜	4
6	2⅛	2½	3	4	4¾
7	2½	3	3½	4⅝	5½
8	2⅞	3[illegible]	4	5¼	6¾
9	3¼	3¾	4½	5⅞	7
10	3½	4	5	6½	7⅝
11	3¾	4¼	5½	7	8¼
12	4	4⅝	6	7½	9
13	4¼	5⅛	6½	8⅜	10
14	4⅝	5½	7	9	11
15	5	6	7½	9⅝	12
16	5½	6½	8	10¼	13
18	6	7¼	9	11¼	14¼
20	6½	8	10	12¾	15½
22	7¼	8¾	11	14	16¾
24	8	9⅝	12	15¼	18½
26	8¾	10½	13	16½	20
28	9½	11⅜	14	18	21½
30	10	12¼	15	19⅜	23
32	....	13⅛	16	20¾	24⅝
34	....	14	17	22¼	26¼
36	....	15	18	23¾	27⅞
38	....	16	19	24½	29½
40	....	17	20	26¼	31¼
42	....	... .	21	28	33
44	....	....	22	29¾	35
46	....	....	23	31½	37
48	.. ..	.. ..	24	33¼	39
50	....	....	25	35	41
52	....	....	26	36¾	43
54	....	....	27	38½	45
56	....	....	28	40¼	47
58	....	....	29	42	49
60	....	....	30	43¾	51

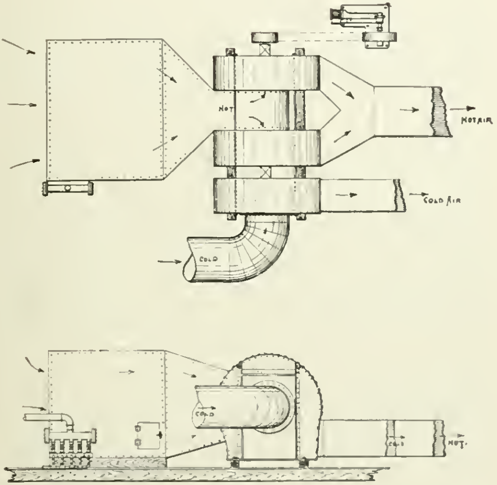


FIG. 22.

Triple Fan designed by M. C. Huyett.

SUPPLEMENTAL.

ANALYSIS OF ALL HEATING SYSTEMS.

DIRECT HEATING.

Stoves, high and low pressure steam, and hot-water systems, having the radiating surfaces in the room to be warmed, class as above; they warm only the air in the room and maintain the heat.

Direct heating and ventilation on a sanitary basis is an impossibility; the two factors are a unit, inseparable; separated, heating is possible, but heating and ventilation is impossible.

STOVES.

A stove ventilates to the extent of the volume of air admitted to the combustion chamber to aid combustion; when the draft is closed ventilation ceases.

In most rooms heated by stoves a comfortable and reasonably equable temperature cannot be maintained; cold drafts exist, caused by the downflow of cold air at windows, which travel at and near the floor line to the stove, where the cold air is taken up by the heat producing power and is again started on its round of travel toward the ceiling, and thence to the coldest side of the room.

GRATES.

A grate fire is bright and cheerful, but it is an expensive means of heating, at least fifty per cent of the heat-producing power of the fuel passes upward and out through the chimney to heat outdoors. An open fireplace, *with a fire in it*, ventilates to the extent of the quantity of air that can leak into the room; to that extent it is an air pump exhausting air from the room, and by the natural law of gravity and atmospheric equilibrium it is replaced by cold air, with the result that one side is "too warm," the other side "too cold," and the lower limbs are exposed to cold drafts. When an open fireplace has no fire in it, in cold weather cold air will fall into a room in volume equal to the leakage of warmer air outward, caused by the heavier cold air falling into and occupying a lower space than the warm air; this action will decrease in proportion as an equilibrium of temperature, as regards internal and external temperature, is restored. An open fireplace should have a closing front or a damper in the throat of the chimney. Make a room air-tight except a keyhole in the door, and the volume of

ventilation produced by a grate fire can be measured by the quantity that can leak in through that hole.

HIGH AND LOW PRESSURE STEAM, AND HOT-WATER SYSTEMS.

High and low pressure steam, and hot-water systems, having the radiating surfaces in the room to be warmed, are direct systems, and on the basis of results produced they are synonymous terms.

In most such applications no attempt is made to secure ventilation ; in some cases flues are provided for the outflow of air, but they DO NOT VENTILATE ; no provision is made for the inflow of air, because to admit air that has not first been warmed is impracticable — it is never attempted.

If heat-force is applied to a ventilating shaft, the volume of ventilation will depend on the size and height of the shaft, amount of heat supplied and maintained, direction and velocity of external air currents, and the quantity of cold air that leaks into the room above sashes and doors ; *no more air can be exhausted from a room than the quantity admitted.*

A comparison of the three gradations of the same system shows high pressure steam — at 25 pounds pressure — the internal temperature of the radiator will be 265° Fahr.; low pressure steam — 5 pounds pressure — 225°, and hot water at from 150° to 212° temperature ; with equal radiating surfaces high pressure will heat a room to a required temperature quickest, low pressure next, and hot water requires the longest time. They will cool in reverse ratio.

The radiating surfaces required will be in proportion to the temperatures, hot water requiring the most, and high pressure steam the least quantity.

Heat is force developed by the combustion of fuel, and when transmitted to water changing it into steam is efficient and economical in proportion to pressure.

Advocates of hot-water systems CLAIM that they are more economical in the consumption of fuel than steam, but the claim does not make a fact ; a given quantity of fuel will produce a certain quantity of heat units, and a given quantity of heat is required to heat a given quantity of air from a given lower to a required higher temperature ; the heat is distributed by the contact of air with the radiating surfaces ; in the hot-water application that contact reduces the temperature of the water in proportion to the heat transmitted from the water to the air, and the water containing the remaining heat circulates back to the boiler where it

absorbs additional heat and is again started on its mission of circulation and transmission.

The advocates of hot-water systems, and many others, have a notion that hot-water heating is healthful, and is preconceived, no doubt, by reason of the sense of feeling. Air so heated has a softness grateful to the sense of feeling and is produced by the accumulation of watery vapor exhaled through the pores of the skin and the result of respiration.

The average quantity of vapor of water exhaled from the lungs daily is 8,100 grains, and from the skin 13,500 grains insensible transpiration without exercise or rise in temperature; 8,100 plus 13,500 equals 21,600, which divided by 24 equals 900 grains per hour.

Now, to fix in mind quantity, assume an average congregation to be 500 persons; $500 \times 900 = 450{,}000$ grains $= 78\frac{1}{2}$ pounds $=$ 9 33-83 gallons of water per hour; this product is not eliminated by the contact of the air with the radiating surfaces — that can only be accomplished by condensation or displacement. By reason of the expanded condition of the air caused by heat the product is absorbed, increasing the relative quantity of vapor of water as compared with natural conditions; to the air thus contaminated by transpiration and respiration is added carbonic dioxide, which, taken together, form conditions weakening and predisposing the system for taking cold, and with exposure to cold drafts or to external air at a low temperature is a frightful source of bronchitis, pleurisy, pneumonia.

The condition is equivalent to a vapor bath, the *only difference is degree*. Occupants of rooms heated by direct systems are more predisposed to the diseases stated than are those who occupy rooms heated by indirect systems.

Dr. F. A. Adams, commenting on the prevalence of pneumonia among persons employed in steam-heated office buildings in an article contributed to the Philadelphia *Record*, rightly suggests that the cause is found in the fact that in the large majority of cases no provision is made for the ventilation of the rooms in such buildings. He says that many of these buildings are admirably constructed to keep out air, whether cold or hot, this very perfection contributing to their insalubrity. In these hermetically sealed office rooms that abound in business buildings the steam heats the atmosphere to a delightfully comfortable degree, the occupant breathes and rebreathes the air during zero days when an open window cannot be endured, the effect being to silently

undermine his powers of resistance, so that when he goes forth, exchanging such tropical air for the keen breeze of unrestricted nature, it happens that, through some subtle change in his system which has robbed his lungs of their power of resistance, their capacity to endure the onset or transition is gone, and the subtle poison of unrenewed air does its deadly work in the form of pneumonia.*

The fact that a room is allowed to cool does not purify the air or remove the animal exhalations. It simply condenses the vapor impurities to be taken up by absorbents; at times the impurities are visible, or sensible to the touch, on non-absorbents such as walls and glass surfaces; after a time the product becomes putrid, but is warmed over time and again, adding to the health-depriving and death-dealing qualities of the air.

DIRECT INDIRECT HEATING.

Direct indirect heating consists of any application of heating apparatus with the radiating surfaces located in the room to be warmed, and, drawing a part of the air contact therewith from exterior to the room, it warms a portion of the interior air. Such applications are possible with high and low pressure steam and hot-water systems, but, by reason of long and slow circulations and consequent danger of freezing, it is seldom applied; *in most cases where the system has been applied it has been abandoned.* When it is applied, the danger of freezing is in proportion to temperature and quickness of circulation. When the system is applied, the volume of ventilation depends on the size and exposure of the radiating surfaces, temperature of the radiating surfaces, temperature of the exterior air, direction and velocity of external air currents, atmospheric pressure, size and height of ventilating shaft, and quantity of heat-force applied therein. It is *impossible to plan or construct such a system to supply a volume of ventilation based on known requirements, constant and controllable.*

An application of this kind means long circulations slow to act, subdivision of heat-force, lack of power to cumulate heat-force at the point of maximum exposure, largely increased radiating surface as compared with direct heating, and which adds proportionately to the cost of plant, and the ever-existing danger of freezing.

Practically, the system is obsolete.

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* "Heating and Ventilation."

INDIRECT HEATING.

Indirect heating consists of any system having the radiating surfaces exterior to the building or room to be warmed.

To treat the subject properly it must be subdivided into several parts, namely: high and low pressure steam and hot-water heating, furnace heating, and hot-blast or mechanical heating.

High and low pressure steam and hot-water heating practically has been covered by the statements of essential elements under the head of direct indirect heating: the only difference is that the indirect system takes its entire air supply from exterior to the building or room to be warmed — it heats none of the air over again.

As a system, the basis of which is rarefaction of air to cause motion and provide volume for ventilation, it has a place in the general heating and ventilating economy; that it does not have more friends is not due to the general principle but to the fact that, in order to lessen first cost, plant installations have been robbed of essentials; radiators have been too frequently used which were not constructed, proportioned, nor installed in such manner as to be efficient and economical.

For ventilation the system depends on area, temperature, and exposure of the radiating surface — for air contact, area of ducts connecting therefrom to rooms to be warmed, area of ventilating flues, height of ventilating flues, and area and exposure of radiating surfaces placed therein. For both heat diffusion and displacement —ventilation — air volume is a prime necessity.

Properly proportioned and scientifically applied it will always prove satisfactory, except under conditions requiring a definite and continuous air supply. Installations should be made for automatic return of water, the result of condensation, to the boiler by means of a low pressure pump and receiver with automatic pump governor; the steam cylinders should have areas to work at fully 50 per cent of capacity with five pounds steam pressure.

Gravity return is practicable in most cases, but for long circulations providing for large volumes of air it should not be depended upon. Gravity return of water is not good practice when fans are used to provide volume of ventilation.

Vertical pipe and flue radiators have been installed and cased in as indirects; they are not suitable for the work.

FURNACE HEATING.

Furnace heating is an indirect system ; when the apparatus is *properly proportioned and applied, it will comfortably warm and sufficiently ventilate private residences.*

In residences, the air space or "breathing space," in proportion to the numbers of occupants, is large, and, as a rule, the building or rooms are aired daily. If the radiating surface is sufficiently large to warm the rooms with economy in fuel consumed, it will have power to remove the volume of air required for ventilation.

When furnace heating, for such a purpose, is not satisfactory, it is caused by the "penny wise and pound foolish" policy of the owner of the building, or the force of competition, or the ignorance and disregard of the natural laws which govern heat and cold by the architect who made the plan, or the person who made the application ; possibly condition is the result of two or more of the elements stated.

In ninety-nine cases out of one hundred the furnace is *too small*, the result is over-heating of the radiator, which warps the joints so that they disperse the fuel gases with the heat product and burn the air to a degree that lessens its life-giving power. A furnace that is "too small" must be "forced," which, by reason of the short circuit for radiation, results in at least fifty per cent of the heat produced by the fuel being rushed up the chimney to "heat all outdoors."

The quantity of fuel consumed by a furnace will be in proportion to the air space to be warmed, area of glass exposures, number of occupants, equable diffusion of the heat product, area of the radiating surface, and volume of ventilation.

In furnace heating, the volume of ventilation depends upon the area, construction, and temperature of the radiating surface, size, length and protection of the hot-air delivery pipes, size and location of the fresh-air inlet, size and location of inlet openings from hot-air pipes, and their location with regard to exposures, size and location of foul-air outlets, external temperature, and direction and velocity of external air currents.

The first essential is to have a proper plan, provided by a competent heating and ventilating engineer, which shall provide for circulation to give diffusion and for ventilation. It is possible to control adverse conditions, and make them servants, but to do so definiteness of plan and common-sense applications must be made.

In most applications the area of air-delivery pipes are not based on proportional air volumes required. No rule for proportioning can be found in print.

The following table and rule is a reliable basis for determining areas of collars, or openings, in casings.

COEFFICIENTS FOR LOW VELOCITIES.

Table of coefficients for determining the size of flue or flues required to change the air in a given room at a given velocity.*
Air travel at low velocities suitable for furnace and indirect steam heating, etc.:

Times air is changed per hour.	VELOCITY IN FEET PER MINUTE.								
	100	125	150	175	200	225	250	275	300
	VELOCITY IN FEET PER SECOND.								
	1.66	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.0
2	4.8	3.9	3.2	2.7	2.4	2.1	1.9	1.7	1.6
3	7.2	5.8	4.8	4.1	3.6	3.2	2.9	2.6	2.4
4	9.6	7.7	6.4	5.5	4.8	4.3	3.8	3.5	3.2
5	12.	9.6	8.	6.9	6.	5.4	4.8	4.4	4.
6	14.4	11.5	9.6	8.2	7.2	6.4	5.7	5.2	4.8
7	16.8	13.5	11.2	9.6	8.4	7.5	6.7	6.1	5.6
8	19.2	15.4	12.8	11.	9.6	8.6	7.7	7.	6.4
9	21.6	17.3	14.4	12.3	10.8	9.6	8.6	7.9	7.2
10	24.	19.2	16.	13.7	12.	10.7	9.6	8.8	8.

* RULE.—Divide the cubical contents of room (in feet) by 100, and multiply the quotient by the coefficient from the table for the times air is to be changed per hour at the given velocity. The result is the area of flue in square inches. (No allowance being made for frictional or other losses.)

In furnace-heated houses, cold drafts prevail and are caused by faulty applications, the result of ignorance. Efficiency of apparatus, comfort for occupants and economy in fuel consumption CAN BE SECURED, but are matters of chance as long as *anybody* can sell a furnace and plan the application. It is safe to state that the efficiency of most furnaces can be increased at least twenty-five per cent, perfect comfort for occupants be secured and fuel bills be reduced from twenty-five to fifty per cent.

The unwholesomeness of furnace-heated air is caused in many instances by the source from which the air supply is taken—frequently from a cellar, or near the ground line, or, possibly, from under a porch, and by contact of the air with over-heated radiating surfaces.

The preceding paragraph refers to furnace applications as ordinarily made. For such buildings furnace heating with mechanical ventilation is not only possible but the experimental stage has progressed so far that it must have place as a mechanical system. While the applications have been empirical by reason of no known data and the fact that the experimenters have been misled with regard to the efficiency of fans and rated volumes, the measure of success has been such as to warrant that the problem in proportion *will be solved;* when that shall obtain heating and ventilation on the basis of a high sanitary standard will come into more general use.

With gas, gasoline, and electric motor powers the problem has been simplified; proper proportion of parts, exposure of radiating surfaces for air contact, and engineering ability is all that is required. The simplicity of such an application will commend it for general use.

Furnace men can readily determine air velocities under average conditions when cold air supply duct shall be wide open. In my opinion 200 feet velocity per minute will be a fair average; no two furnaces are alike and conditions differ, hence velocities will differ. Data for velocities should be secured on the basis of thirty to forty degrees Fahr. exterior air, then large safety factors will be secured.

Applying the table of coefficients: *Example.*—Room 10 by 12, by 10 feet height of ceiling; velocity 200 feet per minute; air to change twice per hour. $10' \times 12' \times 10' = \frac{1,200 \times 2.4}{100} = 28.8$ square inches flue area; at 150 feet velocity the factor is $3.2 = 38.4$ square inches flue area. Furnace pipes are more frequently too large than too small, and in but few instances does proportion enter into the problem.

For house heating, direct-draft furnaces are not economical in fuel. For all furnace work a return circulation (for quick warming and use in extremely cold weather) should be provided; its opening should be in the floor at the coldest place in front hall.

Furnace heating, when *properly proportioned* and *scientifically applied*, is *simple*, *safe* and *economical* for residences, but should be unqualifiedly condemned for use in connection with churches, schools and public buildings where numbers congregate, unless mechanical means for ventilation shall be provided.

Medical experts unanimously agree that the life-giving power of air is greatly lessened by contact with over-heated radiating

surfaces. Such condition will not be possible if full air volume shall be delivered.

In furnace heating "expansion of air" is part of an indefinite theory advanced by interested parties. That the reader may understand that factor:

EXPANSION OF AIR.

(DALTON.)

Temperature. Degrees.	Expansion.	Temperature. Degrees.	Expansion.
32	1.	80	1.110
33	1.002	85	1.121
34	1.004	90	1.132
35	1.007	95	1.142
40	1.021	100	1.152
45	1.032	200	1.354
50	1.043	212	1.376
55	1.055	302	1 558
60	1.066	392	1.739
65	1.077	482	1.912
70	1.089	680	2.028
75	1 099	772	2 312

150 degrees is a high average inflow temperature, and at that the expansion is about twenty-five per cent.

FUEL.

For furnaces — when the furnace is surface feed — the use of Connellsville crushed coke, furnace size, will result in a saving of twenty-five to forty per cent in fuel cost; it is free from cinders, does not make clinkers, and the ash requiring removal will be at least fifty per cent less than from anthracite coal. It requires no more care than coal and retains fire, from fall until spring, with ordinary care; it does not require as much air supply as coal, hence less heat product is forced up the chimney.

For boilers, used with mechanical heating and ventilation, forked lump bituminous coal, or with a mixture of pea size anthracite coal, is most economical.

FUEL DATA.

Up to and including the winter of 1885-6 Chicago Avenue Church, Chicago, Illinois, was heated by seven large furnaces; the winter above stated they consumed ninety tons of anthracite coal; at $5.50 per ton, equals $495.

In December, 1886, the M. C. Huyett Mechanical Heating and Ventilating Apparatus was installed; the building has 615,000 cubic feet of air space, all the rooms of which are used almost continually from 8:30 A.M. until 9:30 to 10 P.M. Sundays, and many

of the rooms are used every day and night; for the winter of 1893-4 there was an average of thirty-five meetings per week; the fuel bill was $339.50.

Trumbull Avenue Presbyterian Church, Detroit, Michigan, has 267,000 cubic feet of air space; the heating plant was put in operation in December, 1887, before the windows were put in, was operated forty-two days consecutively, from ten to sixteen hours each day, and maintained an average temperature of between 70° and 80° Fahr. The high temperature was required by reason of the walls having been laid up when mortar froze as fast as the work progressed, as a result when the heating began the walls glistened with frost.

The fuel used was bituminous coal bought at retail prices, $3.50 per ton, and the cost for the forty-two days averaged $1.10. External temperature ranged as low as ten degrees below zero.

From January 4, 1889, to May 1, the fuel bill was $42.

UNSATISFACTORY MECHANICAL HEATING AND VENTILATION.

Elsewhere data and proof with reference to mechanical apparatus, which has been in use many years are given in detail. The data establish the fact that sufficiency of apparatus, intelligently applied, results in efficiency of apparatus and satisfaction and economy for the user.

Specific statements are made with reference to conditions — made by manufacturers of apparatus — which produce unsatisfactory results for users. Like specific proofs must be submitted, otherwise the reader will naturally assume the statements made are claims, and as the text of this book is not prepared in the interest of any manufacturer of a specific kind of apparatus the proof of unsatisfactory conditions is legitimate; it is not used as an attack on person or principle, but *is used in the interest of architects, the engineering fraternity*, and would-be buyers.

Where mechanical heating and ventilating apparatus is installed and unsatisfactory results are produced the condition is caused by deficiency in the volume of air supply, or lack of proper proportion in the air-delivery pipes, or insufficient radiating surface, or insufficient boiler capacity, or too high velocity of air travel, or faulty displacement of cold air; possibly a combination of the elements causes condition.

The following "history" is proof conclusive with regard to overrating of fan capacities, or under-proportioning heaters, boil-

ers, etc., or incompetent engineering, or a combination thereof, and in addition is proof that a maker's name, claim, reputation, elaborate printed matter, and guarantee, separate from the installation of efficient and sufficient apparatus, and engineering ability, will not make conditions such as to result in good heating and ventilating plants for users.

The "history" emphasizes the necessity for having plans and specifications made by competent engineers.

It is reasonable to conclude that plants installed where designers and manufacturers could give personal attention to construction and application are safe standards of efficiency of apparatus and engineering ability. Those who have made tattooed reputations deprecate the use of "history" and claim "it will hurt the business." In my opinion, *if the business cannot stand the truth it should be hurt.*

Apparatus for the following plants were manufactured, sold and installed by "D":

1. A plant was installed in Young Woman's Home, Detroit, Michigan; was never satisfactory; a part of the price was never paid.

2. Apparatus was placed in Harper Hospital, Detroit, Michigan; the superintendent stated "it cost about $5,000"; was never satisfactory and its use has been abandoned.

3. The Jefferson Avenue Presbyterian Church, Detroit, Michigan (the former building); the price approximated $3,000; it was never satisfactory, about half the contract price was withheld, and after two winters' use a compromise settlement was made and the apparatus *was displaced.*

4. The new "Daily Building," Detroit, Michigan (J. M. & C. W. Daily, proprietors); in 1892 apparatus was installed to heat four floors, connections were made to *two floors only;* it was a failure, the boiler was removed and a second one was installed; then with sixty pounds steam pressure and only *half the promised duty* the plant was a failure. *In June, 1893, the apparatus was removed.*

5. The plant installed in the Hudson Building, Detroit, Michigan; if it was a success, why is 175 horse-power exhaust steam wasted? (Because of back pressure.) And why did the proprietor place radiators in the building?

6. The court records in Detroit will substantiate the following extract from a Detroit daily paper:

"In July, 1889, the ——— put a heater in the wing of the state

prison at Jackson. Warden Hatch claims that he paid their bill, $804.60, on the understanding that when the cold weather came the heater was to be tested, and if it proved unsatisfactory they were to refund the money. The heater, so it was alleged, was a failure and they refused to pay. George N. Davis, Warden Hatch's successor, today began suit against the company to recover the money."

7. The record made in connection with applications to some fourteen school buildings in Chicago, Illinois, is not used.

8. The following extracts are from the Detroit, Michigan, daily papers:

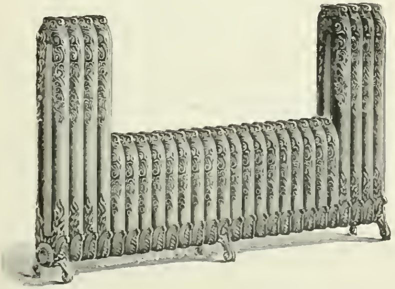


FIG. 22

Perfection Window Radiator.

THE MUNICIPAL COURT BUILDING, DETROIT, MICHIGAN.

To the Honorable the Common Council:

Gentlemen—Your Committee on Public Buildings, to whom was referred the communication from the Health Commissioner calling attention to the want of ventilation and heat of the Municipal Building, respectfully report that we have carefully examined into the matter by personal inspection and are satisfied that the heating and ventilating apparatus placed in said building by

is and always has been inadequate for the proper heating and ventilating of said building, and we are of the opinion that the said manufacturing company have never fulfilled its contract with the City, and as we are informed that said company decline to do anything to make good the defects in their job, we recommend that the City Counselor be instructed to examine the contract between the City and the said

for heating and ventilating the Municipal Building now on file in the office of the Board of Public Works, and report to this Council at its earliest convenience what, if any rights, the City may have in said contract and whether said rights can be enforced against said company.

Respectfully submitted,
J. L. BATCHELDER,
M. W. SCOVEL,
FRANK SCHMIDT.

Accepted and adopted.

PUBLIC BUILDINGS.

To the Honorable the Common Council:

Gentlemen—Your Committee on Public Buildings to whom was referred the matter of properly heating and ventilating the Municipal Building respectfully report that we have examined the heating and ventilating system in the Municipal Court Building and find conditions such as fully justify the complaints so frequently made by the occupants. The building has approximately 324,456 cubic feet of space to be warmed and ventilated. For good ventilation the air supply should be sufficient to change the air at least once each twenty minutes and be supplied constantly.

The principle of the system is right, but the appliances used are faulty.

The fan is a ventilator wheel pattern and as applied will deliver but a small portion of the rated capacity. The result is that the volume of air supplied is not sufficient for good heating and ventilating. Sixteen thousand to 20,000 cubic feet of air per minute is required. If the fan was efficient it would displace that quantity of air from the building through the ventilating flues, regardless of the external conditions. That type of fan will not overcome the load of resistance-friction of air in the hot-air delivery pipes and the resistance caused by the pipes in the heater about which the air is forced by the fan.

To produce the required results a fan and heater is combined The heater is made like the ordinary box; if it was properly constructed it would be divided into three or four separate parts, a small part next the fan to receive the exhaust steam of the engine and utilize its heat-producing power (as applied that heat-producing power is wasted); the remaining two or three parts should be available at will in order that the engineer may control the heat supply without lessening the speed of the fan, and thus reducing the volume of ventilation. When rooms become overheated the occupants must close registers, then ventilation ceases; or the engineer must reduce the speed of the engine, which reduces the volume of ventilation in an increasing proportion as speed of fan reduces.

The heater has one steam supply pipe. If the valve shall be partly or entirely closed, water from the boiler will back into the heater. The return of water (the result of condensation from the coils to the boiler is by gravity through a one-inch pipe) it is insufficient in size. A properly constructed heater, sufficient in capacity, and a fan of the positive type will reduce the cost for fuel and make the building satisfactory as to warmth and ventilation for the occupants. The apparatus is wasteful, insufficient and uncontrollable. To ventilate, air must be supplied. It is impracticable to admit air unless it has first been warmed. If the attempt is made to ventilate the court rooms by placing additional ventilating flues therefrom they will not ventilate unless heat shall be delivered therein, and the volume will be in proportion to the volume of cold air that can leak in about windows or falls into the room through the ventilating outlets now provided. Your committee have endeavored to show you by this report what is wanting and absolutely necessary to the proper heating and ventilating of said building. We therefore recommend that the City Counselor be instructed to notify

that their contract has not been properly carried out and request that they proceed at once to comply with their contract and properly heat and ventilate the building known as the "Municipal Building."

Respectfully submitted,
J. L. BATCHELDER,
M. W. SCOVEL,
FRANK SCHMIDT.

Accepted and leave being granted, the following resolution was offered:

By Ald. Batchelder:

Resolved, That the City Controller be and is hereby instructed to at once notify

that they have failed to fulfill their contract with the city as to heating and ventilating the building known as the "Municipal Building" and to insist that they proceed at once to make such changes as suggested in the above report, that said building may be properly heated and ventilated.

Adopted as follows:

Yeas—Ald. Barnes, Batchelder, Beck, Behlow, Bleil, Buhrer, DeGaw, Deimel, Fisher, Goeschel, Grunow, Hanes, Hoffmann, Jacob, Lowry, Protiva, Richert, Robinson, Roser, Roth, Schmidt, Scovel, Stenius, Vernor, Welsh, Wesch, Wright, Wuellner and the President—29.

Nays—None.

9. Guetzkow Brothers Company, Milwaukee, Wisconsin, bought apparatus of the agent to heat their sash, door, and blind factory; it was a failure, they began a suit for damages.

10. The Wisconsin Bridge & Iron Co, Milwaukee, Wisconsin, is having an experience with an under-proportioned apparatus unscientifically applied.

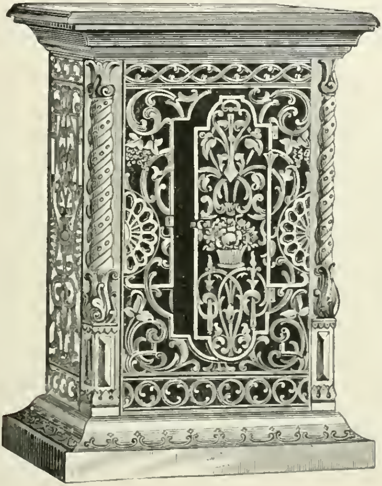


FIG. 23.

Pedestal Screen.

A. B. Church

Room 4, Jorden Block.

Elgin, Ill., June 1st 1897.

Chas. L. Plunkett Esq.
Denver Col.

My dear Sir

Yours 26 rec'd. The System
of Heating, should be a practical way of heatin
and ventilating large buildings - but with us
It was a total failure, and another feature
with us, that was very annoying -. That wit
a Contract -, that they would remove their
apparatus if not absolutely satisfactory; wa
entirely ignored, and compelled us to pay
nearly their full price or go to Law.

The result was - that our System of
Heating cost us $5000 - instead of $2.500 to $3.00

Yours Respectfully
A. B. Church member
Board Trustees 1st Congl
Church of Elgin

Established 1866 Incorporated 1881

Curtis Brothers & Co.,

Manufacturers of

Sash, Doors, Blinds, Mouldings &c.

Clinton Iowa
Wausau Wis

DICTATED LETTER Clinton, Iowa, Sept 9th 1892.

M. C. Huyett Esq.,

Dear Sir:--

Your letter of two weeks or more ago came to hand during my absence from home, hence the delay of my reply.

It is true that the system has never been satisfactory in our high school building here, but two years ago we added the hot water system, and I believe that the two systems combined are now giving fair satisfaction.

In case you have not presented any plans for correcting our system, I will be glad to have any suggestions you may be pleased to offer, which I will promptly present to our Board for consideration.

Yours truly,

[signature]

The instances cited are not isolated cases; they have been used as cumulative evidence with regard to the general statements made by the author.

The *general principle was correct*, but capacities were insufficient, and in some instances poor engineering aided in making the adverse conditions.

The foregoing data are used *reluctantly*, but as buyers weigh one man's *claims* against those of others, made separately, and as men *will verbally claim that which they do not dare put in print*, the buying public must be placed in position to *investigate, otherwise truth has no power*.

CONTRACTS.

SUGGESTIONS TO ARCHITECTS.

Contracts should be free from technicalities, and details should be specifically stated. The most simple form is a proposal from the bidder and formal acceptance by the owner. It is neither wise nor safe to depend upon verbal agreements or understandings.

A proposal should state the cubic contents of each space to be warmed and ventilated × times change of air per hour; total quantity of air per hour and quantity per minute required.

If heating and ventilation shall base on part times change per hour and part a definite quantity of air per person per hour, proposals should state the cubic feet of space to be warmed × times change per hour = cubic feet of air per hour required; to that should be added the following, namely: The number of persons × the quantity of air per person per hour added to the preceding total makes the quantity per hour required, which ÷ 60 = quantity per minute required, and should be so reduced because fan capacities rate on per minute.

2. Height of fan case — approximate.

3. Diameter of fan wheel and its width at the periphery.

4. R. P. M. at which the fan wheel shall be operated to provide the volume of ventilation specified.

5. H. P. required to operate the fan wheel at the R. P. M. designated.

6. Detailed specifications of the boiler, its fixtures, masonry work, smoke flue connection, water and sewer connections, fire tools including a steam flue cleaner, and rated H. P.

7. Engine .... R. P. M. (at ordinary speed) to operate the fan wheel at its designated speed, boiler pressure of steam required, engine foundation, oil cups, wrenches, etc.

8. Oil separator.

9. Injector — if water pressure is under 25 pounds.

10. Heater .... lineal feet of 1-inch steam pipe in the heater. (Reject "feet capacity.") Arrangements for using engine exhaust, boiler pressure required for the heater, and details regarding valves, return water and drips.

11. Pump and receiver with automatic governor.

12. Galvanized-iron air ducts — to connect from the fan to the base of the heat risers connecting to rooms (heat risers and ventilating flues should always be included in the general contract), their areas to be subject to the approval of the heating contractor.

13. Inflow velocities of air to halls and the different rooms in the building.

14. Registers and ventilating plates.

15. "The intent.— The intent is that .... shall furnish, deliver and erect all the material specified, or which has not been specified, necessary for making the installation of the heating and ventilating apparatus a complete whole. It is understood that the heat risers and ventilating flues shall be furnished and erected by the general contractor as per plans and specifications to be furnished by ....; the water service pipe shall be provided with an opening in the boiler room, and sewer-drain openings shall be provided in both boiler and heater rooms ready for .... to connect apparatus thereto."

"All material shall be of standard quality (equal to any in the market); workmanship shall be first-class, and the installation be in accord with modern sanitary engineering practice."

16. Guarantee.— "Guarantee the apparatus shall have capacity for and shall warm the air in the rooms in the building to not less than 65° Fahr. in less than two hours from the time the fan shall be started, when exterior air shall be ten degrees below zero, and shall maintain 70 degrees temperature without unusual crowding the firing; shall provide the full volume of ventilation specified with fan speed as designated elsewhere, and the plant be practically noiseless in operation."

The formal acceptance of a proposition should state the price, and terms of payment.

The heat risers and ventilating flues referred to elsewhere

provide for buildings in course of erection, and where such flues are to be inclosed in walls.

In factories all the exhaust steam should be used in the heater, and the construction should be such as to not cause back pressure on engine.

DEFINITION OF "OR."

Worcester — "a disjunctive particle that marks an alternative, generally corresponds to either."

Century Dictionary — "Choice between two" — "either, else, otherwise, as an alternative or substitute."

Webster — "You may do one of the things at pleasure but not both" — at the same time; "connects two propositions presenting a choice of either." To "use live OR exhaust steam."

CUSTOM.

It is common custom to make apparatus to use live OR exhaust steam in order that live steam may be used nights when continuous heating is desired or to warm a factory prior to morning working hours; at that time no exhaust steam is available because the factory engine would not be in operation. When a factory engine is in operation its exhaust steam should be used for heat production, which otherwise would be loss or waste, and thus save in fuel cost.

BOARDS OF EDUCATION.

Boards of education in all large cities will save money for taxpayers, increase healthful conditions in school buildings, and add to the comfort of occupants by employing competent heating and ventilating engineers; such an officer should be a daily visiting inspector and have control of all janitors, firemen and engineers; and his orders bearing on economy, cleanliness, healthfulness and safety of person and property should be given in writing, in order that in case of appeal to the board the real facts shall be obtainable.

Visits expected at any hour, and any day in the week, to be made by a competent engineer, would change conditions in most school buildings.

Successful results, in heating and ventilating by mechanical means, is simply a problem in proportion, intelligent application, in harmony with natural laws, AND HONESTY.

SUMMARY.

The advantages mechanical heating and ventilation possesses over other systems are :

First.— The quantity of air to be supplied for ventilation can be based on the number of occupants up to or above the highest sanitary standard, and be delivered regardless of the temperature of the radiating surface, internal or external air temperatures, varying atmospheric pressures, direction and velocity of external air-currents, height of ventilating shaft, and heat-force supplied to and maintained therein.

Second.— Temperature and volume of the air, together or separately, changeable at will. Experience has demonstrated the fact that when a room has been warmed sufficiently for occupancy with comfort and safety, if there be many persons the animal heat will so nearly maintain the required temperature that the steam pressure can be largely decreased, or fifty per cent or more of the radiating surface be "cut out," reducing the heat supply without decreasing the fresh-air supply.

Third.— Uniform low temperature of the radiating surface ; the temperature of steam is,

At	5	pounds	pressure	225° Fahr.
"	10	"	"	237° "
"	15	"	"	248° "
"	20	"	"	257° "
"	25	"	"	265° "
"	30	"	"	273° "
"	35	"	"	279° "
"	40	"	"	285 "

But the temperature of the radiating surfaces with which the air to be warmed has contact will not record as high as stated.

Fourth.— No leaky valves, joints and radiators in rooms and corridors.

Fifth.— Quickness with which a building can be warmed. If steam has been used the day previous, a building can be warmed ready for occupancy in from one hour to an hour and a half from the time the fan is started ; when exterior air is at or below zero, starting with water at normal temperature, steam can be made and a building be warmed in about three hours. Under like conditions the average direct-heating systems used in churches requires firing all day Saturdays — and some at night also — and up to the hour for service on Sunday, in order to warm a building sufficiently.

Sixth.— Freedom from inflow of cold air, causing cold drafts, so common in all buildings with warming apparatus which depends on "natural means" to give diffusion and displacement.

Seventh.— The air supply can be conducted from the highest position practicable, insuring pure air, which need not be brought in contact with overheated radiating surfaces.

At what elevation the air of London is purest has been made the subject of scientific investigation by Prim, a chemical expert, the result in question being realized, it appears, at about thirty or forty feet from the ground; lower than that the dust is encountered, and higher, the smoke from the chimneys reaches. Certain experiments in determining this matter were resorted to — that is, frames of wood covered with blanketing material were placed at different elevations, one being put on the top of the clock tower of Westminster, another on the highest point of the roof, and others at varions heights down to the courtyard. After five hours' exposure in these various localities there were found to be more smuts at high elevations than at the low, but on the level of the courtyard considerable quantities of dust were present. The conclusion arrived at is that, on the whole, the purest level is at the height of between thirty and forty feet, nothing being gained by going higher, unless it be to some four hundred or five hundred feet.

Eighth.— All parts of a building or rooms can be heated with like certainty; the full volume of ventilation and heat — force — can be delivered through the ordinary avenues for distribution, or the power can be cumulated at the points of maximum exposure.

Ninth.— Economy in the consumption of fuel; the average architect and heating engineer will probably "receive that statement with a degree of allowance."

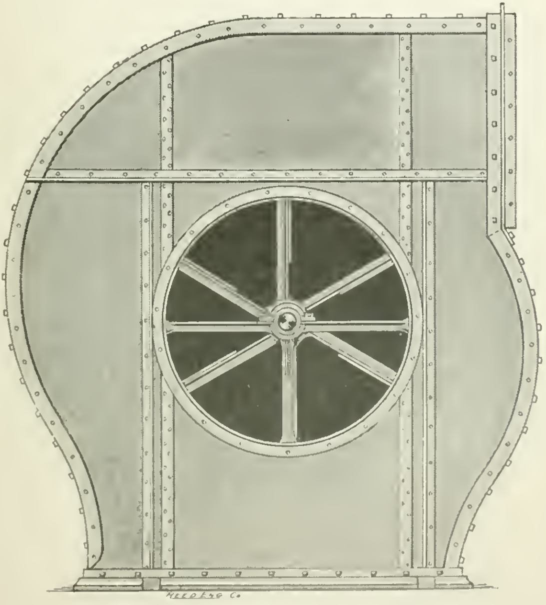
In heating, the combustion of fuel is *cause*, and the warmed air in a building or in rooms is EFFECT, but a like cause does not always produce an equal effect.

Apparatus that will warm the air in an inclosed space in the shortest time, and supply the required volume of fresh air for ventilation at the least expense for fuel, will maintain the after required conditions at the lowest cost.

Where non-continuous heating and ventilation is required — as for churches, schools and other public buildings — the fuel expense will favor hot-blast, or mechanical heating and ventilation, at least twenty-five per cent.

Tenth.— Non-liability of freezing. The radiating surface is less than that required for direct heating, and is all cumulated in one place, with one or two short feed pipes which can be fully protected against loss of heat.

The circulation is short and quick, with automatic return of water — the result of condensation — to the boiler, making the conditions of quick drainage of the radiator, and no danger from low water in the boiler, certainties.



Steel Plate Full Housing Fan Top Horizontal Discharge

All-night firing to prevent pipes from freezing is not necessary. Apparatus which has been through five winters in Wisconsin, with temperature as low as forty-eight degrees below zero, has never had a frozen pipe.

With mechanical heating and ventilation, when a school session closes for the day, or in a church when an audience has been dismissed, the fire, if it has not expired, may be drawn, and the consumption of fuel ceases; the next morning the water in the boiler will not be cold, and one quick fire will ordinarily raise steam and heat the coils in the radiator in less than forty minutes, after which, in about sixty minutes, the building or rooms will be comfortably warmed; subsequently light firing will maintain the required temperature.

A report signed by an expert and a citizens' committee of six persons, who made a critical examination of all school buildings in Chicago, acting with the Board of Education, stated:

"The difference in economy between steam apparatus with and without fan, is demonstrated by the following comparison:

"The average cost per sitting of thirteen buildings without fans, built since 1879, is	$3.14
"The average cost per sitting of all the buildings in which fans are used is	2.71
"The difference in favor of fans is	$0.43

"In these thirteen buildings there are 10,736 sittings, and the departure made in recent years from the fan system has cost $4,616.48 per annum." . . . "Had the fan system been adhered to, it is reasonable to assume that the saving in cost of heating and ventilation during twenty years, the estimated life of the apparatus in these thirteen buildings would have been $92,329.60." . . . "It is evident that materials of an inferior quality have been used in the construction of some of the apparatus." . . . "The results of this inspection have fully demonstrated to the committee the *importance of a careful preparation of the plans for heating and ventilating in connection with the architect's plans.*"

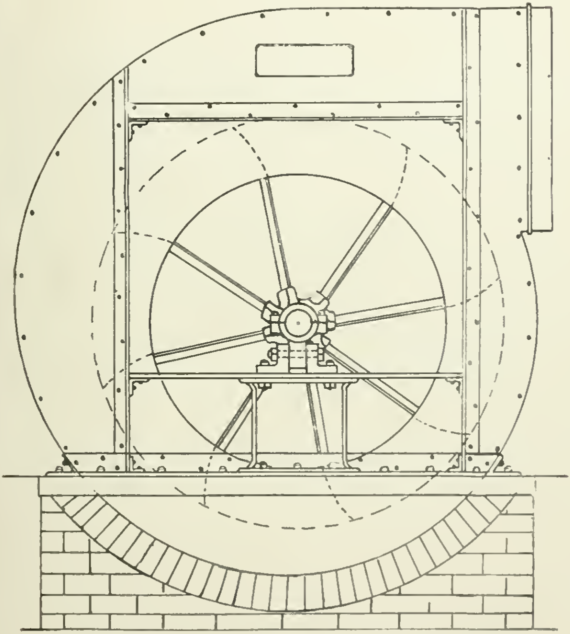
The committee estimated the life of steam apparatus at twenty years, and furnaces at ten years.

The "air space" per pupil ranged from a minimum of 165 to a maximum of 211 cubic feet per pupil.

The result of the examination and report is that since that date, *every school building that has been erected has the fan system* of heating and ventilation.

Hot-blast, or mechanical heating and ventilating apparatus, a complete whole, can be constructed and applied at less cost than any other system that will produce like results, and will maintain required conditions at less cost for fuel.

The foregoing statements are not theoretical; they are demonstrated facts.



Steel Plate Three-quarter Housing Fan Top Horizontal Discharge

DATA.

CHICAGO AVENUE CHURCH (MOODY'S), CHICAGO, ILLINOIS.

Apparatus installed in 1885.

Auditorium, - - -	461,000	cubic feet.
All other rooms (11), -	153,680	" "
Total, - - -	614,680	" "

Two boilers, 35 H. P. each—70 H. P.

127-inch fan, wheel 7 feet by 3 feet at periphery.

Engine, 7 inches by 10 inches, 150 R. P. M.

Heater, 7,000 feet of 1-inch pipe.

Previously heated by seven furnaces; with fuel at $5.50 per ton rate, cost was $495, and the building never was sufficiently warmed

For the winter of 1893–4 the fuel bill was $339.50; averaged thirty-five meetings per week; was used more hours than when the fuel cost was *45 per cent larger.*

TRUMBULL AVENUE PRESBYTERIAN CHURCH, DETROIT, MICHIGAN.

Apparatus installed in 1886.

Cubic feet of space, 267,000.

Boiler, 22 H. P.

Engine 6 inches by 8 inches, 125 R. P. M.

Fan 98 inches, 125 R. P. M.

Heater, 2,880 feet of 1-inch pipe.

For full data, see page 107.

CASS AVENUE M. E. CHURCH, DETROIT, MICHIGAN.

Apparatus installed in 1892.

Is a combination system, *i. e.*, part fan system and part direct radiation.

Auditorium, - - -	128,700	cubic feet.
Chapel, - - -	28,800	" "
Total, - -	157,500	" "

Boiler, 35 H. P. Fan, 90 inches, 150 R. P. M.

Heater, 1,800 feet of 1-inch pipe.

Direct radiation—[quantity cannot be stated].

Electric motor, 5 K.

Eastern Hospital State of North Carolina, Goldsboro, North Carolina.

Cubical contents, 479,000 feet.
Fan, 120 inches. Heater, 4,680 feet of 1-inch pipe.
Engine, 6 inches by 8 inches. Persons, 300.

First Presbyterian Church, Detroit, Michigan.

Cubical contents, 400,000 feet.
Boiler, 50 H. P. Heater, 4,000 feet of 1-inch pipe.
Fan, about 100 inches.
Engine, 6 inches by 8 inches, at about 125 R. P. M.

Leland, Faulconer & Norton Co., Factory, Detroit, Michigan.

First story,	122 x 48 x 12 feet	85,840 cubic feet.
Second "	154 x 48 x 15 feet	103,500 " "
Third "	114 x 48 x 15 feet	82,000 " "
Total,	- - -	271,340 " "

The building is of modern mill construction, large glass exposures, and is exposed on all sides.

Fan, 90 inches; wheel, 54 by 24 inches.

Heater, 2,600 feet of 1 inch pipe.

The apparatus is located on the third floor, is operative either on circulation or with displacement, or in combination. It is one of the most satisfactory and economical working plants in the United States.

SS. Peter and Paul's Cathedral Academy, Detroit, Michigan.

Cubical contents, 300,000 feet.
Fan, 140 inches; wheel, 7 feet by 36 inches at periphery.
Heater, 3,000 feet of 1-inch pipe.
Engine, 7 inches by 10 inches, 150 R. P. M.
Boiler, 45 H. P.; extra to heat residence.

O. C. STEENBERG SASH DOOR AND BLIND FACTORY, FOND DU LAC, WISCONSIN

O. C. STEENBERG,

MANUFACTURER OF

Sash, Doors and Blinds.

Fond du Lac, Wis., May 20 1889

Mr. M. C. Huyett

My Dear Sir:

Yrs, of the 14th asking me how my Hot Blast Heating System which you put in for me in 1885 is working came in my absence.

I think I have replied to the same inquiry from you yearly since it was put in. but it is with pleasure that I state again that it has given me, from the first day we learned how to use it, entire satisfaction. For four winters it has proved a complete success in heating and ventilating my three story factory besides heating three Kilns for drying doors. and has not cost me a cent for repairs. I feel that I can not too highly commend your system of heating, or your system of doing business -

Sincerely Yours,

O. C. Steenberg

WOLFF & NOLLAU SASH, DOOR AND BLIND FACTORY, No. 15 FULLERTON AVENUE, CHICAGO, ILL.

OTTO F. WOLFF — TELEPHONE NORTH 480 — ARTHUR NOLLAU.

OFFICE OF WOLFF & NOLLAU,

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FACTORY: 35, 37, 39, 41, 43 & 45 FULLERTON AVE.

ADJOINING C. & N. W. R'Y TRACK

OFFICE
35 FULLERTON AVE.

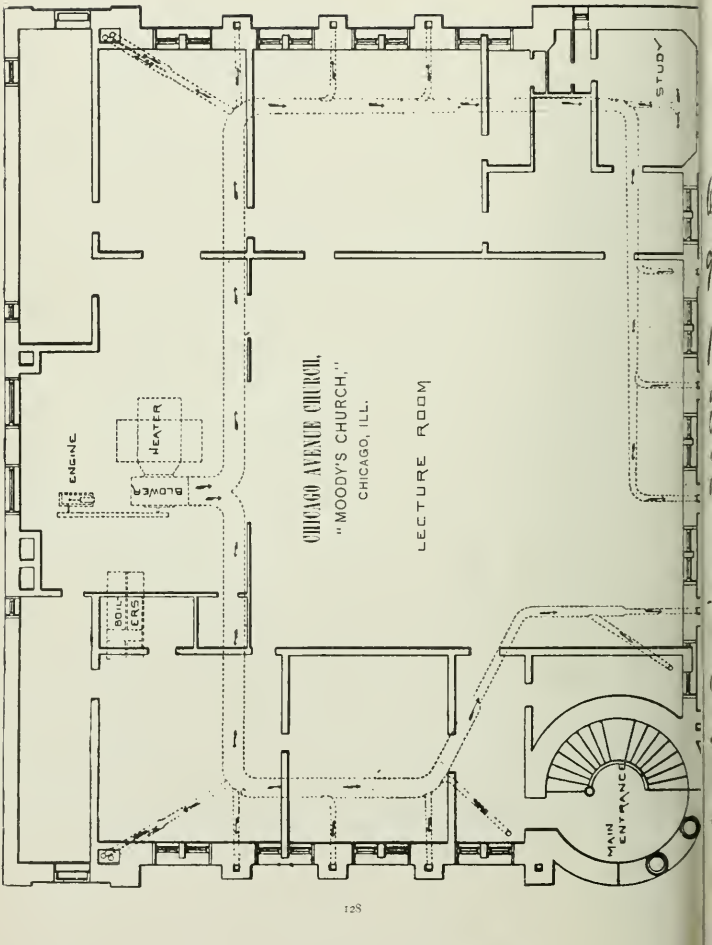
Chicago, Nov. 8th 1894 189

M C Huyett Esq.

1541 Monadnock Building, City.

Dear Sir;- In reply to your letter asking us how we like your xxxx system for heating our factory, also for dry-kilns, will state that we have used the apparatusfor about seven years and in all this time we have had no trouble , we are more than pleased with it ; would have no other. Yours Truly

Wolff & Nollau.


CHICAGO AVENUE CHURCH,
"MOODY'S CHURCH,"
CHICAGO, ILL.
LECTURE ROOM
ENGINE
HEATER
BLOWER
BOIL-ERS
STUDY
MAIN ENTRANCE

Feby 1887

To Whom it may Concern.

The Building Committee of the Chicago Avenue Church. take the greatest pleasure in presenting the following testimonial to the value of the Detroit Hot Blast system of heating and ventilation —

We regard our church both from the size of the audience room (600.000 cubic feet) and the character of the congregation as presenting the most difficult problems both of heating and ventilation, and yet we believe that they have all been satisfactorily solved

I. The entire building can be heated in the shortest possible space of time, an hour and a half or two hours sufficing after the steam has been turned on.

II. This heat can be regulated with almost absolute precision and changes made with great rapidity.

III. A desired temperature can be maintained with constancy.

IV. Perfectly pure air is introduced into the rooms in such quantity and with such power as to displace the foul gases which are generated with such rapidity. They are not left to go if they are so disposed but are pushed out with irresistable power.

V. Not only can heated air be blown through the building in the winter but in the summer, cold air may be forced in the same way, and thus ventilation secured without draughts from open windows.

Without specifying the advantages further. The building Committee hereby expresses its hearty approval of the whole scheme. and its sincere appreciation of the Christian courtesy and business fidelity of the inventor of the system

Mov August.

Rev. Charles F. Goss
Jos A Weeks
A H Lowden

TRUMBULL AVENUE PRESBYTERIAN CHURCH, DETROIT, MICHIGAN

TRUMBULL AVENUE PRESBYTERIAN CHURCH

Detroit Mich

Feby 16 1888

M B Huyett Esq

Dear Sir

In reply to yours in regard to our experience in the Trumbull ave Presbyterian Church and Chapel with the system of Heating put in by the [redacted] Blower Co, The Committe desire to say that it has now been in operation for over a month, in the coldest weather, and under conditions which were not as favorable for testing as are usual in new church buildings, The building had been open all winter, and was chilled through - Walls filled with damp, and the severe winter weather made a difficult test.

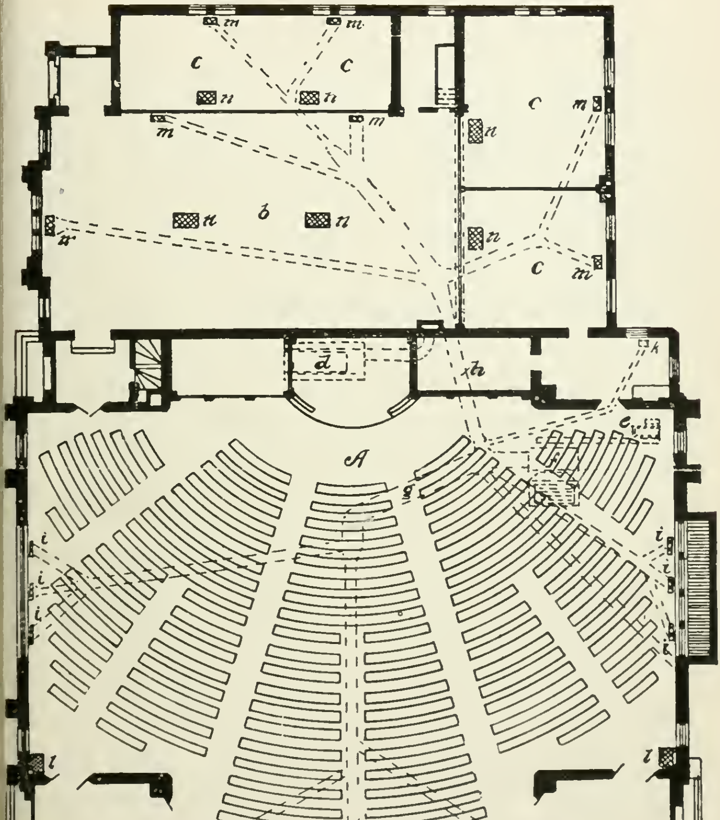
The Building Committe are however perfectly satisfied that this system is the best and most economical that they have ever seen in use, - and the swiftness of it's operation, together with the thoroughness of it's work render it the most practical of all systems of heating.

#2

Steam is raised easily in an hour, turned on to the heating coils which are massed in an Iron upright heating chamber. The Engine starts the fan, and the whole atmosphere in the auditorium soons feels the change. We have no hesitation in say= ing that an hour and a half floods the buildings with pure warm air. There is also a freshness about the [redacted] air, which is constantly changing, that takes away all languor and heaviness from the system, and makes the room very enjoyable.

The system of expelling the air from the floor through an under the church, produces a most perfect system of ventilation, and this regardless of all outside conditions of temperature, as the fan compels a perfect system of ventilation, which under any other circumstances, could not be accomplished.

It is also possible to hold the temperature at any desired point; as by simply shutting the steam off the coils, the air is driven into the building in the same manner, only at a lower temperature.



FLOOR PLAN
TRUMBULL AVENUE PRESBYTERIAN CHURCH DETROIT, MICHIGAN

This renders it adaptable to all kinds of weather and to all circumstances, and gives such an even diffusion of heat all through the buildings, that there are no cold places or corners, all air everywhere being pressed outward, also it is very clear that if the wind currents are strong in one direction, it is quite easy to send the heaviest currents of warm air from the fan to the place where it is most needed, the engine and fan compelling a circulation, that would be otherwise unattainable,

The Economy in fuel is one of its most remarkable peculiarities, and is brought about by the fact that steam is easily held after being made, and the rapidity with which the rooms are heated, there being almost no loss in the transmission of heat from the coil Chamber, to the point of entrance into building. The galvan-ized pipes being perfectly tight, there is nothing lost on the way. The cost of Heating is therefore reduced to the minimum

There is also less danger from fire than under any other system. There is only the one fire under the boiler, ~~which~~ and it is absolutely safe. There are no steam pipes in contact with wood. No fire need be kept over night. The fire can always be made in the morning, and allowed to go out after 8 o'clock in the evening, so that when the building is locked up, there will be no fire anywhere

There seems to be no possibility of any of the pipes freezing, all the steam pipes in the coils being in a vertical position empty themselves, and ordinary caution will protect the pump and engine. There are no exposed places, and we see no reason of any trouble anywhere from exposure to frost, -

Our experience with its operations during the past severe weather, have been very gratifying. It is easily adaptable to all conditions of temperature, can be made to run easily or swiftly, is so nearly noiseless, that it is not

#5

heard in the Auditorium, is easily managed, and is certainly the cheapest and most efficient system of heating large buildings that we have seen. We have had no difficulty whatever with any part of it.

We also desire to say that we thoroughly appreciate your conscientiousness in carrying out, in every detail, the whole system of heating and ventilating as suggested by you. We also desire to say that in regard to the matter of fuel, one ton of soft Coal lasts usually about three days. we believe this would be the average consumption of fuel.

Very Truly Your's

John Cameron
Jefferson M. Thurber
E. W. Dailey

Building Committee

DETROIT, October 26, 1889.

M. C. Huyett, Esq.:

DEAR SIR,—The heating and ventilating apparatus designed by you for Trumbull Aveuue Presbyterian Church has been used two winters, and with results so gratifying that we have no cause for modifying any of the statements made in our letter to you, dated February 16, 1888.

We consider it the most efficient and economical apparatus of which we have knowledge. Our coal bill from January 4 to May 1, 1888, was $42.

Yours truly,

J. M. THURBER.
JOHN CAMERON.
C. W. DAILEY.

Detroit Michigan
July 28th 1892

To whom it may concern

I desire to say that I have known Mr M C. Huyett for the last sixteen years and that I have entire confidence in his ability to carry forward and complete any contracts he may make, and that he is an expert in Steam Heating on the principle of forced circulation by means of the fan and Apparatus as applied by him. He put his apparatus in the Trumbull Ave Presbyterian Church and it has given perfect satisfaction for the past four winters. Any work he proposes to do will be done thoroughly, and to the satisfaction of those who employ him, and that without any prompting.

Very Truly John Cameron.

SS. PETER AND PAUL'S CATHEDRAL ACADEMY, DETROIT, MICHIGAN.

Leon Coquard, Architect, Detroit, Michigan.

EPISCOPAL RESIDENCE.
31 and 33 Washington Avenue

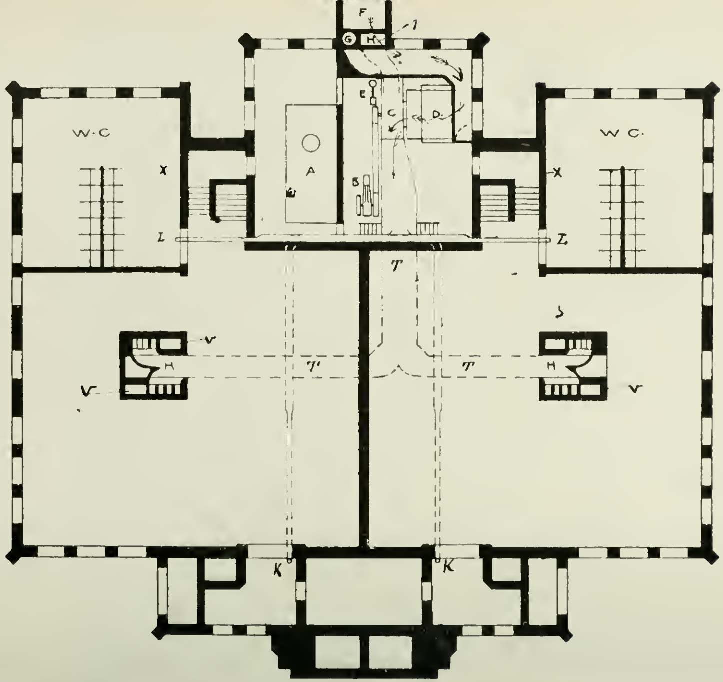
Detroit, Mich. Nov. 29th 1893

Mr. M. C. Huyette Manager:

We take pleasure in certifying to you that the heating and ventilating plant which you placed in SS. Peter and Paul's Academy, is, in our estimation, the most perfect success, especially for ventilation, of any plant which has thus far come under our inspection. We do not claim to give expert testimony, but we do know when a plant gives sufficient heat and can keep the atmosphere of a room pure and fresh. Your plan has succeeded in both these so far and we have no fear but it will continue to give satisfaction. The best commendation we can give is to invite those interested in heating and ventilation to call and examine the plant. Seeing is convincing.

M. J. P. Dempsey Sec.

+ John S. Foley
Bp. of Det.



PLAN — SS. PETER AND PAUL'S CATHEDRAL ACADEMY, DETROIT, MICHIGAN.

Leon Coquard, Architect, Detroit, Michigan.

SS. PETER AND PAUL'S CATHEDRAL ACADEMY.

The detail of apparatus can be found on page 123, and detail of displacement on page 19 and E of page 18.

"A" is boiler, "B" engine, "C" fan, "D" heater, "E" pump and receiver; "F" cold air supply shaft with inlet opening forty-two feet from the ground line; the base opening is under the smoke flue "G" and heat riser "H 1"; they are carried on steel beams.

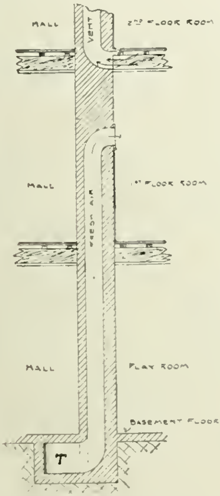


Fig. 24. Heat riser to first floor and ventilating flue for second floor, SS. Peter and Paul's Cathedral Academy. Third floor rooms are a like application.

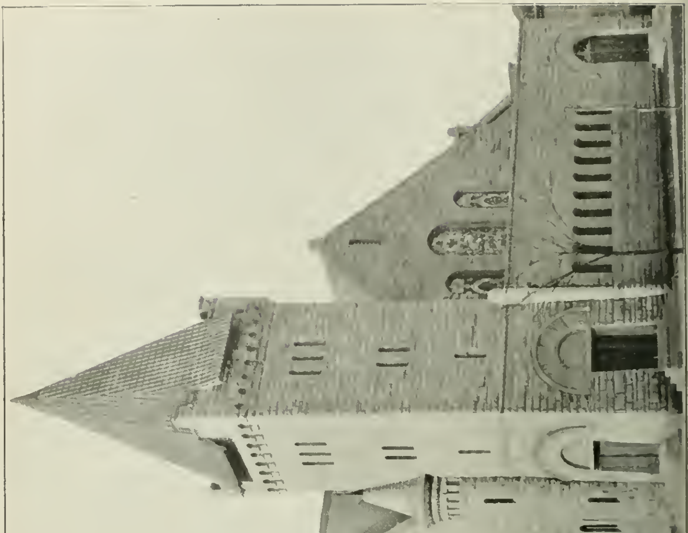
The air in its passage to the heater "D" is kept separate from the basement air, and after passing through the heater, is forced by the fan "C" into the tunnel "T" and "T T" to the eight heat risers at their terminals.

The water-closet room ventilating flues are in the walls at "X" and "X," with displacement separate from all other outlet shafts.

"K K" is heat to the front of each hallway, and "L L" is heat to each toilet room.

"H 1" delivers heat to the large room immediately over the boiler and machinery room and to the assembly hall, which occupies the space on the second and third floors. "V V V V" are ventilating flues.

The first floor has five large class rooms, office, cloak rooms, and four exits; the second floor, four large class rooms, two recitation rooms, and cloak rooms; the third floor, two large class rooms, two recitation rooms, and cloak rooms. The assembly hall with its gallery, stage, etc. occupies second and third floor space.



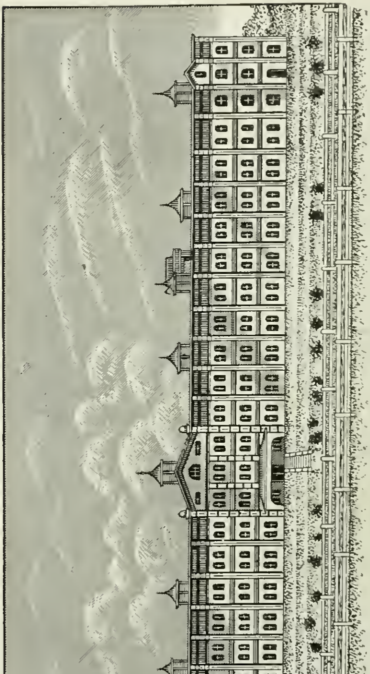
CASS AVENUE M. E. CHURCH, DETROIT, MICHIGAN

Detroit. Mich. March 15. 1894.

M. C. Huyett Esq
Chicago
Dear Sir

As a member of the Building Committee of the Cass Avenue M E Church of this city I am very glad to say that the work done by you for us in putting in the heating system for that plant with blower and radiator combination has been entirely satisfactory. Your work has been done without any pressing, urging or fault finding on either side and we have found you more than willing to make any changes or improvements as the work progressed or since it was finished that seemed to promise to be of advantage to us or to make the plant as near perfect as circumstances would permit

Yours very truly
D. W. Porter



EASTERN NORTH CAROLINA HOSPITAL FOR THE INSANE, GOLDSBORO, NORTH CAROLINA.

The Eastern Hospital

DR J. F. MILLER, Superintendent,

Goldsboro, N. C. July 23 1897

Mr M C Huyett

Detroit Michigan

My Dear Sir:— It is my pleasure to state that "the heating & ventilating apparatus by M. C Huyett" has given entire satisfaction. The amount of heat has always been sufficient but at first the heat was not properly distributed in all parts of the building — too much in some of the wards & not enough in others this was afterwards easily corrected, our Hospital building is now well ventilated &

also well heated. Our building is composed of a center building 4 stories high & about 40 ft square, divided into 4 rooms & two halls on each floor; & also two wings each 3 stories high & 150 ft long, each floor in each wing containing from 30 to 36 rooms. On one wing there is also attached a building 36 × 96 ft with a basement room 36 × 42 ft in size, ~~this building~~ is also 3 stories in height & is used as dormitories for patients, for an infirmary & work & assembly room, the basement for an associated dining room. I send you a cut of our building. Respect

J. J. Miller

Leon Coquard,
ARCHITECT,
27 Abbott St., DETROIT, MICH

DETROIT March 7, 1894

MR M. C HUYETT,
Heating and Ventilating Engineer,
Chicago Ill

Dear Sir.-

Your kind favor inquiring if the Heating and Ventilating apparatus in SS Peter and Paul's Academy is giving satisfaction was duly received.

Everything is running smoothly and economically--which is a great point in favor of the system as installed by you.

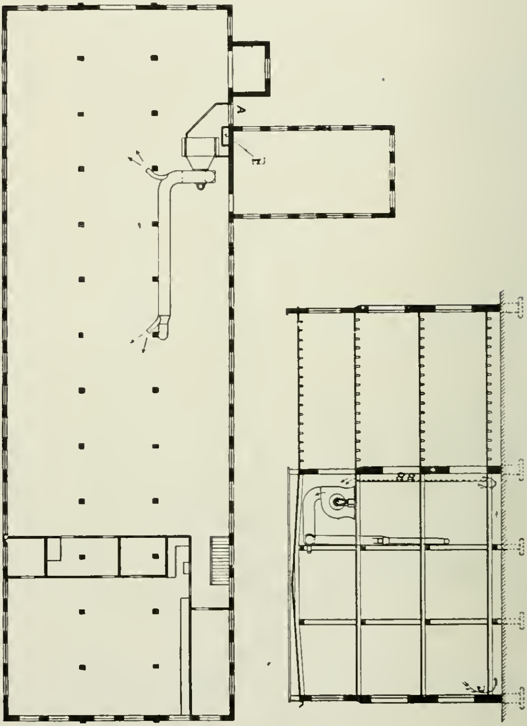
I am simply delighted with the results, and feel satisfied that there is not one other school building in this state, which is as thoroughly heated and ventilated, and has so complete and perfect a plant

Should any one require information regarding your work here I shall be pleased to answer all inquiries

Yours very truly,

Leon Coquard

Section.



Section.

PLAN—LELAND, FAULCONER & NORTON CO. FACTORY, DETROIT, MICH.

R. E. Raseman, Architect, Detroit, Mich.

R. C. FAULCONER Prest
HENRY M LELAND, Vice Prest
CHAS A STRELINGER Sec'y & Treas
CHAS H NORTON Mech Eng

Leland, Faulconer & Norton Co.
Manufacturers of
MACHINERY & TOOLS.
96 TO 104, BATES STREET,
Detroit, Mich., U. S. A.

DEC 21st. 1893

M. C. HUYETT, Manager

GENTLEMEN.-

The Heating and Ventilating Apparatus in our Works is giving excellent results The Fan & Engine attached are well made and run as smoothly as any mechanism of its class we ever saw

The air-pipes are neatly and substantially made The arrangement for the use of live or exhaust-steam is complete and the Heater in connection with the system of air-circulation arranged by your Mr. M. C. Huyett, is warming our Works in a very satisfactory manner

With the exception of a few hours, the exhaust-steam from our Engine has kept our Works warm during the day, after the temperature has been raised with Live-steam before starting Engine, and we have every reason to believe that it would do so the entire winter if our Engine was run up to its full capacity (or sixty horse power)

We believe the success of the Apparatus is due as much to the system of air-circulation arranged by Mr Huyett as to the Heater itself

Very truly yours

LELAND, FAULCONER & NORTON CO.

ST FRANCIS DE SALES SCHOOL, TOLEDO, OHIO.

W H Webster Architect, Hartford Block, Toledo, Ohio.

W. G. MALCOMSON W. E. HIGGINBOTHAM.

MALCOMSON & HIGGINBOTHAM,
ARCHITECTS.

OFFICES 53 & 54
MOFFAT BUILDING.
DETROIT, MICH.

Mch. 15 94.

Mr M. C. Huyette,

Dear Sir, referring to yours of recent date just received, We have only one story to relate concerning the warming and ventilating plant of the Cass Ave. M. E. Church, provided and set in place complete by you, and that is to the effect that the execution and practical working of entire apparatus is all that can be reasonably desired and the plant is giving good satisfaction under the well known trying conditions of Detroit Climate

Very respectfully yours
Malcomson & Higginbotham

JULIUS HESS
Architect and Superintendent,
44 BUHL BLOCK.

DETROIT, MICH., Mar. 7, 1894

M. C. HUYETT; Esq

Heating & Ventilating Engineer.

Chicago Ill

Dear Sir.--

It was my privilege to inspect the first Hot Blast Apparatus you constructed in 1885, and then comprehending the possibilitie of application for Heating and Ventilating large buildings, endorsed the main princioal.

In 1887 I was Architect for the Trumbull Ave Presbyterian Church in this City, you installed your Fan and Heater in that building, it has been and is perfectly satisfactory, and other than grate bars, has not cost, since then, $5 00 for repairs

I have carefully examined your work, installed in SS Peter & Paul's Academy in this City, and consider it to be the bes application in aocord with natural laws that govern heat, cold and vitiated air

Yours respectfully,

Julius Hess

SPECIAL NOTICE.

Unfortunately my name is associated with and forms part of a corporate name with which I have had *no connection since 1885 — a date prior to the development of mechanical heating and ventilating apparatus.*

M. C. HUYETT.

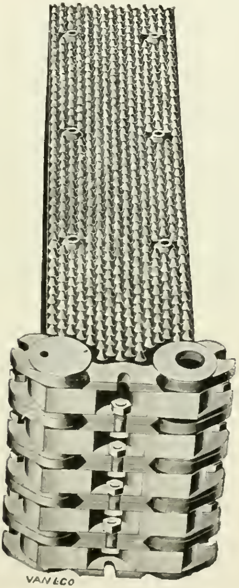


FIG. 25.

Complete Stack Perfection Pin Indirect Radiator.

M. C. HUYETT,

Heating and Ventilating Engineer,

CONSULTING ENGINEER,

EXPERT WITNESS IN LEGAL CASES.

— AND —

Superintendent of Large Constructions.

Plans and Specifications for Heating and Ventilating Apparatus analyzed and Expert Reports made without fear or favor for Architects and Owners.

Plans and specifications for Heating and Ventilating, Power and Electrical Installations made for Architects and Owners.

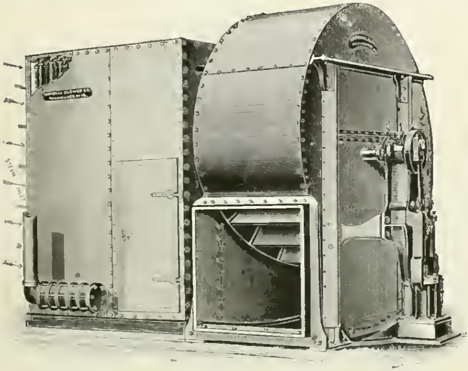
MONADNOCK BUILDING,

CHICAGO, ILL.

NATIONAL BLOWER CO.

MANUFACTURERS OF

Steam Hot Blast Apparatus



FOR HEATING AND VENTILATING

Schools, Churches, Factories, Etc.

Send for Catalogues, References, Plans, etc.

NATIONAL BLOWER CO.

Main Office and Works:

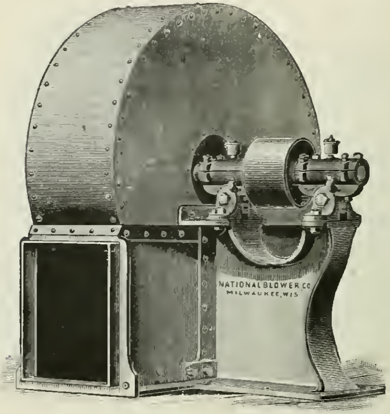
732-766 Greenbush St., - MILWAUKEE, WIS.

NATIONAL BLOWER CO.

MANUFACTURERS OF

SINGLE AND DOUBLE

Steel Plate Exhausters



For Conveying Shavings, Sawdust, Etc.

FANS FOR ALL PURPOSES.

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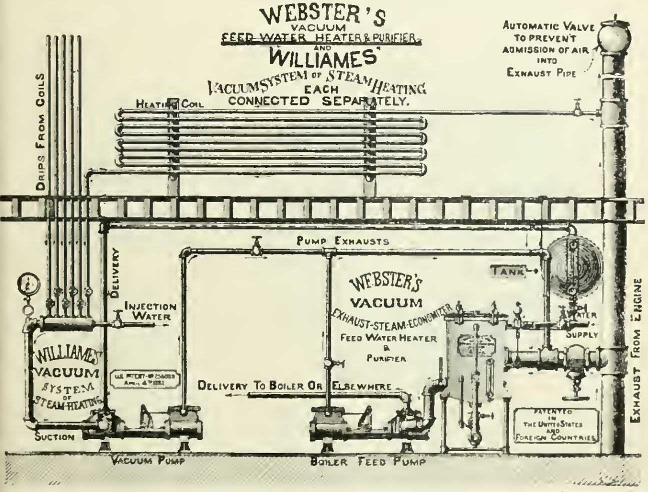

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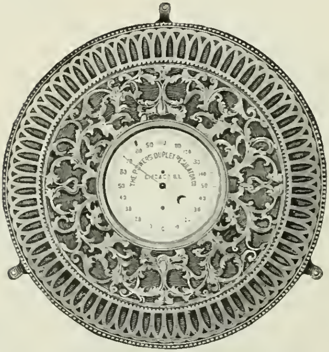

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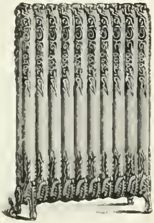

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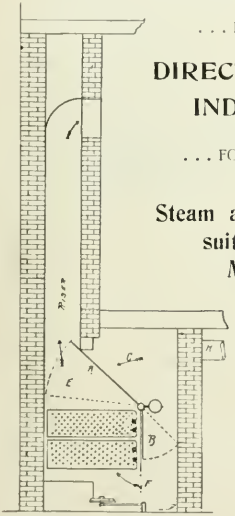

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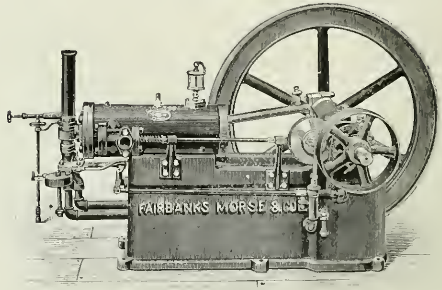

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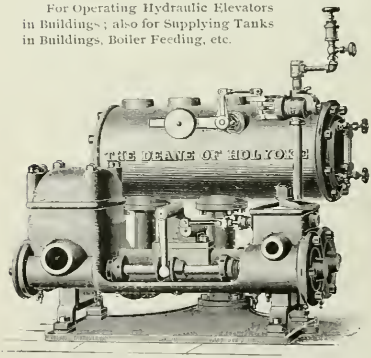

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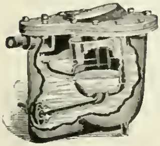

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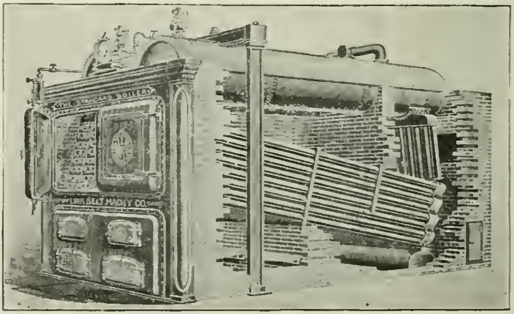

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